

Internal Letter



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Subject: Prediction of Orbiter RSI Tile Gap Heating Ratios from
NASA/Ames Double Wedge Model Test Data

References:

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(NASA-CR-160147) PREDICTION OF ORBITER RSI

N79-20067

TILE GAP HEATING RATIOS FROM NASA/AMES

DOUBLE WEDGE MODEL TEST (Rockwell

International Corp., Downey, Calif.) 85 p

Unclass

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Summary

In-depth gap heating ratios, $q(z)/q_{ref}$, down Orbiter RSI tile sidewalls were predicted based on near steady state temperature measurements obtained from Double Wedge Model tests performed in the NASA/Ames 20MW Arc Heater Facility. The objective of the analysis was to derive gap heating ratios which would result in the best fit of test data and which could be used to provide an assessment of open gap response and the definition of gap filler requirements on the Orbiter. A further objective was to compare these heating ratios with previously derived ratios based on the NASA/JSC Wing Glove Model tests, in order to verify the extrapolation of the Wing Glove data to Orbiter flight conditions. The analysis was performed with the Rockwell TPS Multidimensional Heat Conduction Program (XF0031) for a 3-D, 2.0-inch thick flat RSI tile with 255 nodal points. The data from 14 tests (4 test conditions, 2 gap widths and 2 wedge angles) was used to correlate with the analysis. The results showed that the best-fit heating ratios at the station farthest upstream on the model for most gap depths were less than the extrapolated values of the Wing Glove Model heating ratios. For the station farthest downstream on the model, the baseline (zero-pressure gradient) heating ratios adequately predicted or over-predicted the test data.

1.0 Introduction

During reentry of the Orbiter, a potential problem of overheating down the RSI tile sidewalls exists in regions of high pressure gradient. An extensive test program in the 10MW Arc Jet Facility at NASA/JSC using a Wing Glove Model was conducted (Ref. 1) to determine the in-gap temperature response on the model in high pressure gradient regions. Using this Wing Glove data, derived values of heating ratio down the gap were obtained for five test conditions (Ref. 2). Gap heating correlation functions were then obtained, based on this Wing Glove data, and extrapolated to various regions of the Orbiter (Ref. 3) to identify where gap filler may have to be installed.

In order to verify the extrapolation of the Wing Glove data to Orbiter flight conditions and to provide further experimental data at higher values of pressure and pressure gradient, another extensive test program was performed to determine in-gap heating. This program was conducted at the 20MW Arc Heater Facility of NASA/Ames using a semi-elliptic nozzle corresponding to the test requirements listed in Ref. 4. A double-wedge model was used with adjustable rear wedge angle to vary the pressure gradient for the same general value of surface pressure. Fourteen successful tests were performed at four general levels of surface pressure. In-depth thermocouple data at four axial stations along a 15° gap inclined to the flow was used to compare with the analysis.

The thermal analysis was performed using the TPS Multidimensional Heat Conduction Program described in Ref. 5. For each test, the reference heating rates and surface pressures at the top of each stack were input to

the math model as a function of time for each arc-jet test. The rest of this document will present a summary of the experimental test program (including model description, instrumentation, and test conditions), a description of the analytical model, and the results obtained from the correlation with the data.

2.0 Experimental Test Program

2.1 Description of Model

A Double Wedge model approximately 18 inches wide by 20 inches long was mounted at the outlet of the semi-elliptic duct at the NASA/Ames 20 MW Arc Heater Facility. A photograph of the model installed in the facility is shown in Fig. 1, showing the three RSI tiles surrounded by Silfrax blocks. Downstream of the tiles was an adjustable rear wedge made of Silfrax which was mounted at 0° and -6° to the horizontal. Underneath this rear wedge a plenum was located (see Fig. 1) which provided a low pressure sink for the model.

The upstream transverse gap of the model was open three inches to either side of the inclined gap and filled with Fiberfrax out to the Silfrax side border tiles. This Fiberfrax filler extended from the surface to about 1 in. down into the gap. The adjustable Silfrax rear wedge was butted against the Silfrax and RSI tiles with no gap filler.

The front wedge tiles on the model varied in thickness from 1.30 inches at the leading edge to 2.00 inches at the trailing edge. The center tiles were curved pieces 2.00 inches thick at the leading edge, varying to about 2.16 inches at the middle of the tile. A side view of the Double Wedge model showing the attachments to the SIP, aluminum plates, steel mounting plate, and model test holder is presented in Fig. 2. In Fig. 3 an isometric view of the model is presented which shows the Silfrax side border pieces which served as flow-field fences to prevent the flow streamlines from turning off the rear wedge.

2.2 Model Instrumentation

A total of 55 thermocouples and 14 pressure sensors were mounted on the Double Wedge model as seen in the sketch of Fig. 4. This figure shows the location of the surface, in-depth, and combined surface and in-depth thermocouples in the various stacks. The RSI tiles were instrumented with Pt-Pt/13% Rh thermocouples, while the aluminum baseplate was instrumented with Chromel/Constantan thermocouples. Also shown in Fig. 4 are the location of the surface and in-gap pressure sensors on the model. The plenum pressure measurement was located at sensor no. 19 shown in Fig. 4.

Table I presents an instrumentation list for the Double Wedge tests. This list shows the in-depth measurements in the RSI tiles down to about 1.8 inches below the surface. There were four principal stacks

of thermocouples located along the 15° inclined gap that were of major concern for data correlation. These included T/C stacks B3, F2, D3, and H2 which were located, respectively at 0.75, 2.0, 3.5, and 5.0 inches from the upstream gap transverse to the flow.

2.3 Test Conditions

There were 14 successful tests which were performed using the Double Wedge model that were used for data correlation. Four specific test conditions were performed described as "Conditions 1, 1-1/2, 2 and 3" which corresponded to relative levels of the arc pressure. Two gap widths, 0.030 inch and 0.060 inch, and two rear wedge angles, 0° and -6° were used for conditions 1, 1-1/2 and 2. Only the 0.030 inch gap width was used for condition 3.

The actual levels of arc pressure for the four test conditions are presented in Table II along with values of mass flow rate, arc current, voltage, power and the various enthalpies listed for each test condition. It should be noted that the values of arc pressure, current voltage, and power shown in Table II represent average values obtained during subsequent Double Wedge tests with gap filler installed (Ref. 6). This data was not recorded on the computer printout during the open gap tests (Runs 17-32), but the test conditions were approximately the same as those for the open gap tests. The runs were all terminated at 400 sec; hence all test data described in this document was recorded at 390 sec.

Other flow properties for the tests for which only approximate conditions could be obtained include nozzle exit Mach No. (~ 5), Reynolds No. based on nozzle length (1×10^5 - 2×10^5), and boundary layer thickness over the model (1 inch $\pm$ 0.5 inch). The flow was not fully turbulent for condition 1, but was fully turbulent for the other test conditions (Ref. 7).

There are three values of enthalpy shown in Table II. Since there was not adequate instrumentation to determine losses in total energy in the arc heater, only an approximate value of enthalpy could be obtained. It may be seen that there is a considerable difference between the mass average value and the stream core value. According to Ref. 8, for heat transfer to the Double Wedge model, the appropriate value of enthalpy will be greater than the mass average value but probably not as high as the core value. The enthalpy values listed in Table II are no more accurate than $\sim 10\%$ according to Ref. 8. The significant aspect of the enthalpies is that, no matter how they are calculated, the ratios of the enthalpies to each other are nearly constant. That is, $h_1/h_{1-1/2} \sim 1.58$, $h_1/h_2 \sim 2.28$, and $h_1/h_3 \sim 2.50$.

3.0 Test Data

3.1 Pressure and Pressure Gradient

Table III presents the values of surface pressure and pressure gradient for each test at the four T/C stacks investigated: B3, F2, D3, and H2. Also listed in Table III are the values of the parameter $(P)^{1/2}(\Delta P/\Delta X)$. This parameter was used in plotting heating ratio as discussed in Section 5.2. The maximum surface pressures on the model at P11 are also shown in Table III. These values of pressure varied from about 28 PSF for Test Condition 1 to about 80 PSF for Test Condition 3.

The surface and gap pressure distribution along the model as a function of distance downstream of Tile No. 1 are shown in Figs. 5-18, for Tests 17 through 32, respectively. Faired curves through the test data are shown in these figures for ease in determining the pressure gradient at any location. It may be seen that for all tests the gap pressure is lower and has a lower slope than the corresponding surface pressure until approximately 4 inches downstream of Tile No. 1 where the gap pressures drop sharply to the value at the plenum. For the same wedge angle the gap pressures for 0.06 inch width are about 10-15% higher than those for 0.03 inch gap width, even though the gap pressures (and surface pressures from about 4-7 inches back of Tile No. 1) are higher at 0° wedge angle than at -6° wedge angle because of the flow expansion along the rear wedge.

Fig. 18A shows a composite plot of the gap and surface pressures for Runs 25, 26, 27, and 28. From this figure a comparison can be made between the levels of pressure for each of the four test conditions.

3.2 Temperature

The measured temperatures at $t=390$ sec. are shown in Tables IV and V, respectively for the first two T/C stack locations (B3 and F2) and for the second two T/C stack locations (D3 and H2) along the side of the 15° inclined gap. In addition to the in-depth values the surface values are also listed at E2 (near stack B3), G3 (near stack D3), and D2 (near stack H2). Stack F2 had a thermocouple practically on the surface (.01 inch). All of the gap thermocouple depths listed in Tables IV and V were obtained from X-ray photographs and are generally different from the nominal values ($Z=0.1, 0.3, 0.6, 1.2,$ and 1.8 inches) as seen for some of the stacks listed in Table I. The surface values at E2, F2, G3, and D2 were used for the reference heating rate driver for the thermal math model as described in Section 4.0.

The surface temperatures at E2, F2, G3, and D2 are shown as a function of upstream surface pressure at location 11 in Figs. 19-22 and in

Figs. 23-26 as a function of the approximate local surface pressure (obtained from Figs. 5-18). In Figs. 19-22 the surface value at B2 is also shown. This value was not used as a reference value since there was a surface value at F2. However, the surface temperatures at F2 were all within 4% of those at B2.

As seen in Figs. 19-26, the surface temperatures all increased from Condition 1 to Condition 1-1/2, generally all decreased from Condition 1-1/2 to Condition 2, and then increased again from Condition 2 to Condition 3. The decrease in surface temperature from Condition 1-1/2 to 2 was probably caused by additional cold mass flow injected downstream of the arc heater in an attempt to achieve a near-constant surface temperature (Ref. 7). The increase in temperature from Condition 2 to 3 was probably caused by the table angle being moved up 3° at the leading edge of the model in order to bring the surface temperature back up. This probably caused some of the flow to spill over the model (before it reached the end plates), reducing the boundary layer thickness and consequently increasing the surface temperatures (Ref. 7). Also the increase in table angle could have caused a weak shock over the model, also increasing these surface temperatures.

In order to expedite the analysis of the Double Wedge data, not all of the T/C stack data for each of the runs were used. For the runs with 0.03 inch gap only the cases with the 0° wedge angle (Runs 25, 26, 27, and 28) were evaluated in detail. As a check, one run for 0.03 inch gap, wedge angle of -6° (Run 32) was evaluated. A comparison with the data showed that the data was similar at each stack; hence no correlations were made for Runs 29, 30, and 31 other than with the zero pressure gradient gap heating curve. This similarity in test data may be seen in Figs. 27-30 which show the in-depth temperature comparison between data from Runs 28 and 32 for stacks B3, F2, D3 and H2, respectively. Similarly, the in-depth temperature data for Runs 27 and 31 are shown in Figs. 31-34 for stacks B3, F2, D3, and H2, respectively.

4.0 Analytical Model

The thermal math model developed for this study was based on the one-quarter flat tile model shown in Fig. 35. The model used in the analysis had a 2-inch thick section of LI-900 RSI, and the coating was considered to be reaction cured glass (RCG) material, 0.015 inches thick with a surface emissivity of 0.85. The Nomex felt strain isolation pad (SIP) was 0.16 inches thick and the aluminum plate behind the SIP was 0.125 inches thick. A 1.0-inch thick block of Silfrax was considered to be mounted behind the aluminum plate. The back face of this Silfrax block was considered to be an adiabatic surface. The initial temperature for all surfaces was assumed to be 70°F.

The Rockwell XF0031 thermal analyzer program was used to perform the analysis of the math model which had a total of 255 nodal points. This

finite difference program used the Crank-Nicolson method with a mid-difference implicit numerical analysis technique to integrate the 3-D heat conduction equation. A 2-D cross-string method was used to compute radiation view factors down the gap for the appropriate gap widths (.03" and .06") and the XF0031 Program calculated the script-F radiant interchange factors across the gap based on these input view factors. The material thermal properties were obtained from the Space Shuttle Program Thermodynamic Design Data Book (Ref. 9).

The reference heating rate was input to the math model as a function of test time at each stack by computing $q_{ref} = \alpha \epsilon_w T_w^4$ where T_w (in degrees Rankine) was the measured surface temperature at the top of each stack of E2, F2, G3, and D2, corresponding to the in-depth measurement at stacks B3, F2, D3, and H2, respectively. No attempt was made to use cold wall heating rates as there were no measured values of this heating rate or measured values of enthalpy available. In addition to the reference heating rate at the stack being analyzed, the reference heating rate at the stack immediately adjacent to the stack was input to account for lateral conduction effects (although this lateral conduction was small compared to the in-depth conduction down the tile sidewall). The surface pressure measurement (or interpolated value) at the location of each stack was also input to the model as a function of time so that the material properties could be calculated as a function of pressure as well as temperature.

An assumed value of heating ratio, $q(z)/q_{ref}$ for each of the nodal points down the gap was input to each stack analyzed. The computed temperatures at each nodal point were plotted and compared with test data. An adjustment to the gap heating ratio was made on the next run, and the corresponding temperatures were compared with data. This process was continued until the predicted temperatures were within 30°F of the test data. These best-fit heating ratios were calculated at the first three stacks on the model. For the last stack (H2) the baseline (zero-pressure gradient) heating ratio was used since the pressures and temperatures were so low at this stack. The baseline heating ratio proved to be conservative for all of the cases analyzed at this stack.

5.0 Results from Analysis

5.1 Temperatures

5.1.1 Results at 390 Sec

The last time point before the arc jet runs were terminated was 390 sec; hence this was the point at which the data was used for the best-fit analysis. Table VI shows the predicted

in-depth temperatures for each run analyzed at T/C stack B3 for $t=390$ sec. Table VII shows corresponding predicted temperatures for the other stacks analyzed (F2, D3, and H2). The comparison of predicted best-fit temperatures with the Ames Double Wedge Model data at $t=390$ sec is shown in Figs. 36 through 46. Several of the plots have two or more stacks shown (all have stack B3). The comparison for stack F2 is shown for Runs 24, 27, 28, and 32, while the comparison for stack D3 is shown for Run 24.

In Figures 36 through 46 there are two data points at which it was impossible to achieve a close fit with the predicted temperatures. These data at loc. B3 were for Run 17 ($z=0.63$ in.) and for Run 20 ($z=1.20$ in.). In order to achieve a fit to this data it would have required an abnormal reflex in the heating ratio curve. It was thus assumed that these two test data points were in error. For most of the other data points the predictions are within 20°F of the data.

Also shown in Figures 36 through 46 are the surface temperature data. At the first stack (B3), the surface data is usually lower than the predicted value at the top of the gap. This is because the response at the in-depth thermocouples at B3 (0.15" and lower) down the gap is controlled by high pressure gradients and radiation non-relief effects in the gap.

In Figures 47 through 50 the predicted temperatures using the baseline (zero pressure gradient) heating ratio are shown plotted as a function of distance down the gap for Runs 29-32, respectively, for stack H2. The data for Runs 25-28 is shown on these figures as well as the data for Runs 29-32. It may be seen that using the baseline heating ratio adequately predicts or overpredicts the data at all points for this gap station, which is the farthest station downstream on the model with the lowest surface pressure. The baseline curve for Run 32 (Fig. 50) is somewhat higher than the data than for the other cases analyzed (Figs. 47 through 49). This could be due to the effect of higher pressures for this case and/or higher reference heating rates input to the model at the upstream T/C stack at D3.

5.1.2 Transient Results

The gap in-depth temperatures as a function of time for five sidewall depths are shown in Figs. 51 through 55 for location B3 and Runs 18, 25, 26, 27, and 28, respectively. From these plots it is seen that excellent agreement with the data occurs at the last time point, but that fairly poor agreement with the data occurs during the early time period. This poor agreement was probably because the heating ratios used in the analysis were based on hot wall values at the end of the test, whereas during the early part of the test (coupled with the normal early arc jet transients)

the wall was cold, producing higher reference heating rate measurements than radiation equilibrium and used in the analysis. This deviation at early test times is not felt to be significant for Orbiter flight conditions since the rates of change of temperature on entry are slow compared to the test environment in the arc-jet facility.

5.2 Heating Ratio

The desired "best-fit" heating ratios down the gap sidewall for all of the tests analyzed are shown in Table VIII for T/C stack B3 and in Table IX for T/C stacks F2, D3, and H2. In Table IX the heating ratio shown for T/C stack H2 is the baseline value which drops to zero at $z=0.40$ in. The heating ratios are plotted as a function of gap in-depth distance in Figs. 56 through 62. Figures 56 and 57 show the ratios for -6° wedge angle and 0° wedge angle, respectively, for the 0.060" gap width at T/C stack B3. For both Figures 56 and 57 the heating ratio for conditions 1-1/2 and 2 are fairly close together, whereas the ratio for condition 1 is significantly lower. This is because the measured surface temperatures and the gap to surface temperature ratio for condition 1 are lower than those for condition 1-1/2 and 2 as seen in Figures 36 and 39, and Table IV.

Figure 58 shows the variation in heating ratio with in-depth distance for the first three stacks for Run 24. It may be seen that the ratios for the first two stacks (B3 and F2) are close together and are significantly higher than those at stack D3. This is because of the significant gap pressure drop near stack D3.

In Figure 69 the best fit heating ratios at stack B3 are shown for 0.03 in. gap width and zero wedge angle for Runs 25, 26, 27, and 28 (Conditions 1, 1-1/2, 2, and 3, respectively). The ratio for Run 26 is close to that of Run 27 up until about $z=0.6$ in. since the temperature data is similar up to that point (see Figures 43 and 44). The heating ratio for Run 28 is significantly higher than Run 27 for most of the distance down the gap because of the higher pressures and pressure gradients associated with this condition 3. Figures 60 through 62 present the heating ratio for the first two stacks (B3 and F2) for Runs 27, 28, and 32, respectively. The ratios for Run 28 are significantly higher than Run 27 because of the higher pressures while those for Run 32 are fairly close to those of Run 28 because of the similar pressure between Run 28 and Run 32 (both at Condition 3).

A comparison of the heating ratio for the Ames Double Wedge Model tests with the ratio for the JSC Wing Glove Tests (Ref. 1) is shown in Figure 63 as a function of the parameter $(P)^{1/2}(\Delta P/\Delta X)$. The Double Wedge

data shown is taken at the first stack (B3) down from the transverse gap while the Wing Glove data shown is at T/C stack 39, also the first stack downstream from a transverse (stagnation line) gap. The data shown is for three in-depth locations: $z=0.1, 0.25, \text{ and } 2.0 \text{ in.}$ It may be seen that in general the nominal 0.03 in. and 0.06 in. gap width Double Wedge heating ratios are lower than the Wing Glove heating ratios.

It should be noted that the Wing Glove model had an initial gap width of 0.06 in. in the vicinity of T/C stacks 37, 38, and 39. During the course of a test the aluminum back plate would be expected to expand, allowing the gap to expand to greater than 0.06 in. For the Double Wedge tests, however, each tile was mounted on a separate aluminum plate; hence the gaps stayed at a constant width (either 0.03 or 0.06 in) during the course of a test.

An extrapolation of the Wing Glove data in Fig. 63 to higher values of $Pl/2\Delta P/\Delta X$ would show higher values of the heating ratio than for the Ames nominal 0.06 in. gap width data. This would be expected because of differences in boundary layer thickness, configuration and attitude, etc. between the models and test facilities.

Figures 64A and 64B show the gap heating ratio at various gap depths for gap widths of 0.03 and 0.06 in. for the parameter $Pl/2\Delta P/\Delta X=30$ and $50 \text{ PSF}^{3/2}/\text{in.}$, respectively. This range of the parameter is characteristic of the maximum values that will be experienced on the Orbiter during the near-constant heating rate period from about 450 sec to 750 sec (Ref. 10). It may be seen that the heating ratios for 0.03 in. gap width are significantly lower than those for the width of 0.06 in. for corresponding gap depths.

6.0 Conclusion

A description of the analysis and results of deriving in-depth heating ratios, $q(z)/q_{ref}$, down the sidewalls of the Orbiter RSI tiles was presented in this document. These heating ratios were derived from best-fit temperature predictions of the test data obtained on a Double Wedge model tested in the NASA/Ames 20MW Semi-Elliptic Nozzle Arc Heater Facility. The analysis, performed with the Rockwell XF0031 TPS Multidimensional Heat Conduction Program, showed very good correlation (within 30°F) for most of the test data. It was seen that the majority of the Double Wedge model heating ratios for gap widths of 0.03 and 0.06 in. gap widths were lower than the ratios for the Wing Glove model of Ref. 1. It is expected that the gap heating correlations

presented in this document will be used to provide further assessment of gap filler requirements at critical points on the Orbiter fuselage/chine and wing glove regions.

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TABLE I. INSTRUMENTATION LIST FOR AMES DOUBLE WEDGE TESTS

A. THERMOCOUPLES

Tile No.	T/C Loc On Tile	T/C* Depth (In.)	T/C No.	T/C Chan. No.	Tile No.	T/C Loc on Tile	T/C* Depth (In.)	T/C No.	T/C Chan. No.
2	A2	0.1	1	401	1	A1	Surf	27	427
		0.3	2	402		B1	Surf.	28	428
		0.6	3	403		C1	Surf.	29	429
		1.2	4	404		D1	Surf	30	430
		1.8	5	405		A3	0.1	31	431
	B2	Surf.	6	406			0.3	32	432
		0.1	7	407			0.6	33	433
		0.3	8	408		B3	1.8	35	435
		0.6	9	409			0.15	36	436
		1.2	10	410			0.36	37	437
		1.8	11	411			0.64	38	438
	C2	Surf.	12	412			1.20	39	439
	D2	Surf.	13	413			1.79	40	440
	E2	Surf.	14	414		C3	Surf.	41	441
	F2	0.01	15	415		D3	0.14	42	442
		0.08	16	416			0.31	43	443
		0.37	17	417			0.61	44	444
		0.56	18	418			1.20	45	445
		1.16	19	419			1.79	46	446
		1.73	20	420		E3	Surf.	47	447
	G2	Surf.	21	421		F3	Surf.	48	448
	H2	0.11	22	422		G3	Surf.	49	449
		0.29	23	423		H3	Surf.	50	450
		0.57	24	424			A1 Base	51	
		1.21	25	425				52	
		1.79	26	426				53	
								54	
								55	
								56	

*Nominal values are 0.1, 0.3, 0.6, 1.2, and 1.8 in. Other values listed were obtained from x-ray photographs

B. PRESSURE SENSORS

Loc.	Channel No.	Loc.	Channel No.	Loc.	Channel No.
1	51	12	62	17	67
2	52	13	63	18	68
3	53	14	64	19	69
4	54	15	65	20	70
11	61	16	66		

TABLE II. APPROXIMATE TEST CONDITIONS FOR AMES DOUBLE WEDGE TESTS

TEST CONDITION	RUN NO.	TEST PERIOD	I^0 (Amps)	V^0 (Volts)	P^0_{ARC} (PSI)	GAP WIDTH (IN.)	REAR WEDGE (IN.)	$h_{mass\ av.}$ (BTU/LB)	$h_{cond\ 1}$ $h_{cond\ 2}$	$h_{stream\ core}$ (BTU/LB)	$h_{cond\ 1}$ $h_{cond\ 2}$	$h_{sonic\ flow}$ (BTU/LB)	$h_{cond\ 1}$ $h_{cond\ 2}$	$V_{surf\ max}$ (in)	$P_{surf\ max}$ (PSI)	AP/AX (PSI/IN.)
1	17,22,25,29	10/77-11/77	0.40	1520	6.515	4268	48.2	-6.0	5200	1.000	1.000	9360	1.000	1076	28.8	2.87
1-1/2	20,23,26,30	10/77-11/77	0.65	1856	6.878	4423	92.8	-6.0	3780	1.585	1.585	5900	1.576	1962	39.3	3.77
2	10,24,27,31	10/77-11/77	0.93	1546	7.298	4724	118.0	-6.0	2300	2.261	2.261	4140	2.289	1978	48.5	4.80
3	26,32	11/77	1.06	1541	7.360	4794	126.7	-6.0	2050	2.537	2.537	3690	2.467	2038	81.3	7.60

*AVERAGE VALUES OBTAINED FROM DOUBLE WEDGE TESTS WITH GAP FILLER

**AT 1/2 L2

*AT P11

TABLE III. NASA/AMES DOUBLE WEDGE SURFACE PRESSURE & PRESSURE GRADIENT DATA

RUN NO.	COND.	GAP WIDTH (IN.)	WEDGE ANGLE (°)	B3 (0.75")				F2 (2.00")				D3 (3.5")				H2 (5.0")			
				$\frac{\Delta P}{\Delta X}$ (PSF/IN)	P_{B3} (PSF)	$(P_{B3})^{1/2}$ [(PSF) ^{3/2} /IN]	$\frac{\Delta P}{\Delta X}$ (PSF/IN)	P_{F2} (PSF)	$(P_{F2})^{1/2}$ [(PSF) ^{3/2} /IN]	$\frac{\Delta P}{\Delta X}$ (PSF/IN)	P_{D3} (PSF)	$(P_{D3})^{1/2}$ [(PSF) ^{3/2} /IN]	$\frac{\Delta P}{\Delta X}$ (PSF/IN)	P_{H2} (PSF)	$(P_{H2})^{1/2}$ [(PSF) ^{3/2} /IN]	$\frac{\Delta P}{\Delta X}$ (PSF/IN)	P_{H2} (PSF)	$(P_{H2})^{1/2}$ [(PSF) ^{3/2} /IN]	
17	1	0.060	-6	2.53	25.7	12.83	2.75	22.3	12.98	2.05	18.1	12.11	2.90	13.8	10.76	2.90	13.8	10.76	
18	2	0.060	-6	4.47	43.0	29.32	4.70	37.4	28.76	4.75	30.3	26.13	4.85	23.0	23.28	4.85	23.0	23.28	
20	1-1/2	0.060	-6	3.33	34.4	19.55	3.65	29.9	19.97	3.85	24.4	19.02	3.90	18.8	16.93	3.90	18.8	16.93	
22	1	0.060	0	2.67	25.3	13.43	2.55	22.0	11.96	1.88	18.4	8.07	1.50	15.6	5.93	1.50	15.6	5.93	
23	1-1/2	0.060	0	3.77	34.0	21.98	3.35	29.4	18.16	2.68	24.7	13.32	1.58	21.0	7.24	1.58	21.0	7.24	
24	2	0.060	0	4.80	42.0	31.10	4.30	36.4	25.93	3.53	30.4	19.45	2.20	25.6	11.13	2.20	25.6	11.13	
25	1	0.030	0	2.87	25.0	14.35	2.60	21.7	12.12	2.23	18.0	9.46	1.80	14.8	6.93	1.80	14.8	6.93	
26	1-1/2	0.030	0	3.68	33.9	21.42	3.38	29.4	18.32	2.95	24.7	14.66	2.45	20.5	11.10	2.45	20.5	11.10	
27	2	0.030	0	4.73	42.6	30.89	4.30	36.9	26.10	3.75	30.7	20.78	2.80	25.9	14.25	2.80	25.9	14.25	
28	3	0.030	0	7.60	71.7	64.37	7.15	62.4	56.49	6.25	52.1	45.13	4.90	43.4	32.29	4.90	43.4	32.29	
29	1	0.030	-6	2.70	25.7	13.69	2.88	22.3	13.59	2.88	18.1	10.63	2.88	13.6	10.63	2.88	13.6	10.63	
30	1-1/2	0.030	-6	3.63	35.5	21.64	3.80	30.9	21.13	4.15	24.8	20.67	4.15	18.5	17.85	4.15	18.5	17.85	
31	2	0.030	-6	4.10	44.0	27.18	4.70	38.3	29.09	5.35	30.6	29.59	4.85	22.6	23.04	4.85	22.6	23.04	
32	3	0.030	-6	6.67	72.2	56.70	7.40	63.5	58.98	8.30	51.6	59.59	8.95	38.6	55.58	8.95	38.6	55.58	

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TABLE IV. MEASURED TEMPERATURES AT t=390 SEC FOR 1ST 2 T/C LOCATIONS FOR AMES DOUBLE WEDGE TESTS

RHH TEST NO. COND.	GAP WIDTH (IN.)	WEDGE ANGLE (°)	E2		B3		F2										T/C CHANNEL NO.	
			T ₀ Z=0"	T ₀ Z=0.15"	T ₀ Z=0.36"	T ₀ Z=0.64"	T ₀ Z=1.2"	T ₀ Z=1.79"	T ₀ Z=2.01"	T ₀ Z=2.08"	T ₀ Z=2.37"	T ₀ Z=2.56"	T ₀ Z=2.71"	T ₀ Z=2.86"	T ₀ Z=3.01"	T ₀ Z=3.16"	T ₀ Z=3.31"	T ₀ Z=3.46"
17 1	0.060	-6	414	436	437	438	439	440	415	416	417	418	419	420	420	420	420	420
18 2			1876	1957	1925	1891	1317	878	1642	1897	1787	1624	1139	705				
20 1-1/2			1970	2285	2211	2066	1783	1305	1848	1968	1969	1972	1714	1229				
22 1		0	1952	2219	2135	2042	1894	1296	1933	1964	1964	1900	1717	1144				
23 1-1/2			1826	1968	1945	1784	1231	830	1873	1868	1785	1550	1108	676				
24 2			1962	2244	2210	2123	1761	1180	1965	2004	2032	1984	1598	1060				
25 1	0.030		1978	2296	2212	2085	1686	1230	1876	1998	2002	1993	1648	1166				
26 1-1/2			1859	1725	1596	1257	694	358	1843	1785	1442	1210	592	257				
27 2			1939	2015	1897	1578	958	543	1937	1899	1637	1380	782	354				
28 3			1950	2008	1851	1571	1023	622	1838	1783	1575	1346	835	445				
29 1			2030	2269	2194	2066	1541	1069	1988	2018	1879	1723	1308	863				
30 1-1/2		-6	1849	1770	1560	1263	682	359	1819	1754	1465	1170	577	247				
31 2			1959	2015	1877	1562	944	541	1954	1908	1631	1359	768	350				
32 3			1939	1990	1848	1591	1053	649	1837	1761	1569	1353	844	461				
			2038	2305	2215	2123	1612	1138	1989	2011	1870	1730	1326	894				

NOTE: ALL TEMPERATURES IN °F AT t=390°F

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TABLE V. MEASURED TEMPERATURES AT t=390 SEC FOR 2ND 2 T/C LOCATIONS FOR AMES DOUBLE WEDGE TESTS

RUN NO.	TEST COND.	CAP WIDTH (IN.)	WEDGE ANGLE (°)	G3			D3			D2			H2			T/C CHANNEL NO.
				T ₀ Z=0"	T ₀ Z=1.14"	T ₀ Z=1.31"	T ₀ Z=1.61"	T ₀ Z=1.2"	T ₀ Z=1.79"	T ₀ Z=0"	T ₀ Z=1.11"	T ₀ Z=1.29"	T ₀ Z=1.57"	T ₀ Z=1.21"	T ₀ Z=1.79"	
17	1	0.060	-6	449	442	443	444	445	446	413	422	423	424	425	426	426 + T/C CHANNEL NO.
18	2			1651	1565	*	1074	*	260	1584	1348	1132	795	230	61	
20	1-1/2			1643	1556	*	1251	*	508	1457	1219	1050	769	271	72	
22	1		0	1787	1692	*	1294	*	436	1612	1359	1176	856	279	67	
23	1-1/2			1627	1539	*	1069	*	227	1609	1212	933	613	151	59	
24	2			1825	1655	*	1266	*	413	1637	1193	913	616	147	76	
25	1	0.030		1656	1522	*	1222	*	457	1453	996	781	522	153	48	
26	1-1/2			1673	1522	*	898	*	99	1611	1397	1142	768	213	59	
27	2			1789	1598	*	1019	*	123	1626	1359	1153	785	201	45	
28	3			1690	1495	*	948	*	125	1471	1214	1005	663	157	39	
29	1		-6	1800	1628	*	1226	*	301	1562	1265	1111	783	219	78	
30	1-1/2			1714	1532	*	916	*	93	1593	1412	1209	858	250	61	
31	2			1853	1616	*	1039	*	117	1629	1428	1243	894	252	53	
32	3			1660	1484	*	967	*	135	1464	1292	1119	797	204	46	
				1815	1646	*	1254	*	330	1568	1371	1259	951	277	84	

NOTE: * BAD OR QUESTIONABLE DATA
ALL TEMPERATURES IN °F AT t=390 SEC.

TABLE VI. PREDICTED TEMPERATURES FOR AMES DOUBLE WEDGE TESTS AT T/C STACK B3

DEPTH (IN.)	TMM NODE NO.	RUN 17	RUN 20	RUN 18	RUN 22	RUN 23	RUN 24	RUN 25	RUN 26	RUN 27	RUN 28	RUN 32
0.025	705	1931	2180	2261	2027	2245	2280	1778	2022	2070	2305	2329
0.075	711	1947	2179	2262	2002	2243	2278	1781	2031	2075	2309	2319
0.125	717	1960	2186	2266	1992	2250	2278	1762	2015	2057	2301	2311
0.175	723	1964	2188	2264	1981	2252	2273	1728	1989	2029	2288	2300
0.250	729	1956	2178	2248	1957	2245	2260	1658	1932	1971	2259	2276
0.400	735	1908	2137	2198	1891	2211	2217	1502	1793	1833	2194	2212
0.625	741	1789	2041	2099	1758	2125	2125	1251	1555	1602	2069	2088
0.875	747	1613	1904	1961	1561	1995	1988	965	1262	1331	1874	1908
1.125	753	1401	1736	1793	1330	1817	1802	709	976	1064	1638	1687
1.375	759	1175	1556	1610	1102	1601	1566	521	740	843	1402	1457
1.625	765	965	1377	1431	902	1366	1358	404	578	692	1193	1250
1.875	861	810	1231	1285	754	1174	1171	342	485	600	1041	1098
2.000	795	649	1082	1164	593	1060	996	214	296	405	808	870

NOTE: ALL TEMPERATURES IN °F AT t=390 SEC

TABLE VII. PREDICTED TEMPERATURES FOR AMES DOUBLE WEDGE TESTS AT T/C STACKS F2, D3, & H2

DEPTH (IN.)	TMM NODE NO.	T/C STACK F2				T/C STACK D3		T/C STACK H2			
		RUN 24	RUN 27	RUN 28	RUN 32	RUN 24	TMM NODE NO.	RUN 29	RUN 30	RUN 31	RUN 32
0.025	706	2017	1811	2041	2029	1622	705	1602	1691	1515	1714
0.075	712	2007	1804	2050	2008	1595	711	1526	1610	1446	1684
0.125	718	2015	1779	2048	1993	1573	717	1453	1533	1379	1623
0.175	724	2020	1741	2032	1973	1548	723	1383	1460	1314	1550
0.250	730	2020	1675	1993	1937	1504	729	1280	1353	1218	1435
0.400	736	1998	1530	1882	1855	1406	735	1081	1150	1032	1215
0.625	742	1927	1301	1703	1705	1239	741	812	874	779	920
0.875	748	1807	1044	1511	1518	1037	747	545	594	528	624
1.125	754	1650	810	1304	1320	832	753	340	372	334	390
1.375	760	1455	624	1098	1138	651	759	208	227	207	237
1.625	766	1239	496	924	987	513	765	137	147	138	153
1.875	862	1057	423	805	878	429	861	106	112	107	118
2.000	796	911	328	629	844	337	795	81	83	81	85

NOTE: ALL TEMPERATURES IN °F AT t=390 SEC

TABLE VIII. DERIVED HEATING RATIOS, $q(z)/q_{ref}$ FOR AMES DOUBLE WEDGE TESTS AT T/C STACK R3

DEPTH (IN.)	TMM NODE NO.	RUN 17	RUN 20	RUN 18	RUN 22	RUN 23	RUN 24	RUN 25	RUN 26	RUN 27	RUN 28	RUN 32
0.025	705	0.360	0.650	0.750	0.700	0.740	0.780	0.120	0.300	0.360	0.555	0.600
0.075	711	0.140	0.170	0.200	0.150	0.185	0.210	0.072	0.100	0.105	0.108	0.085
0.125	717	0.094	0.110	0.130	0.097	0.115	0.125	0.048	0.052	0.055	0.059	0.055
0.175	723	0.080	0.088	0.100	0.082	0.0895	0.091	0.035	0.048	0.050	0.052	0.050
0.250	729	0.066	0.071	0.078	0.068	0.0730	0.074	0.0245	0.039	0.041	0.043	0.046
0.400	735	0.052	0.055	0.056	0.053	0.0570	0.058	0.0140	0.025	0.027	0.040	0.040
0.625	741	0.039	0.042	0.044	0.041	0.0462	0.047	0.0087	0.0145	0.0157	0.037	0.0345
0.875	747	0.028	0.034	0.036	0.026	0.0400	0.041	0.0065	0.0095	0.0124	0.029	0.0300
1.125	753	0.020	0.027	0.029	0.016	0.0315	0.033	0.0053	0.0077	0.0100	0.0216	0.0235
1.375	759	0.0145	0.022	0.023	0.013	0.0220	0.025	0.0046	0.0065	0.0086	0.0175	0.0185
1.625	765	0.0110	0.018	0.019	0.0115	0.0130	0.017	0.0041	0.0058	0.0080	0.0148	0.0155
1.875	861	0.0084	0.0145	0.016	0.0083	0.0085	0.0095	0.0038	0.0052	0.0076	0.0130	0.0138
2.000	795	0.0072	0.0130	0.015	0.0064	0.0065	0.0070	0.0036	0.0050	0.0074	0.0120	0.0130

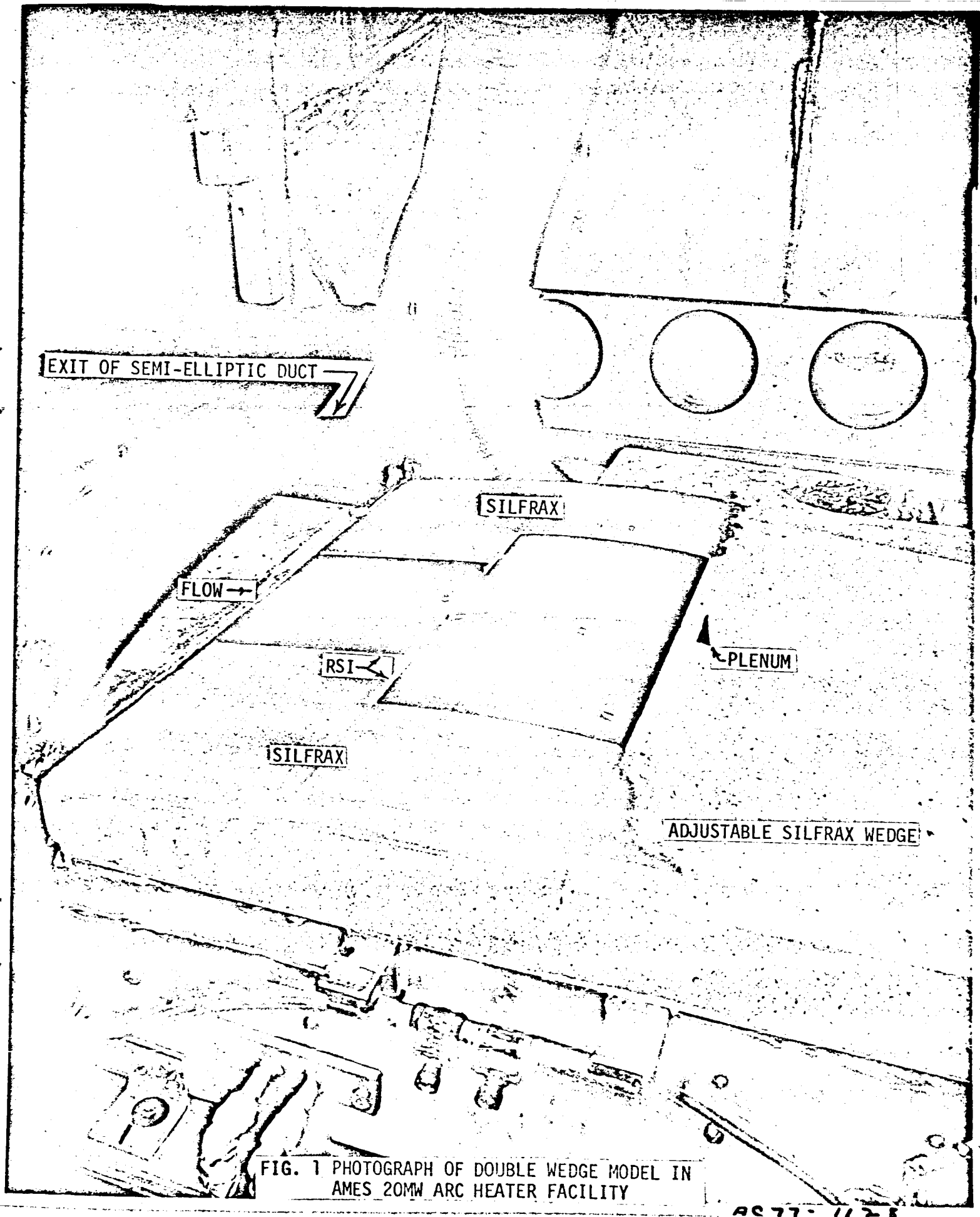
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TABLE IX. DERIVED HEATING RATIOS, $q(z)/q_{ref}$ FOR AMES DOUBLE WEDGE TESTS AT T/C STACKS F2, D3, & H2

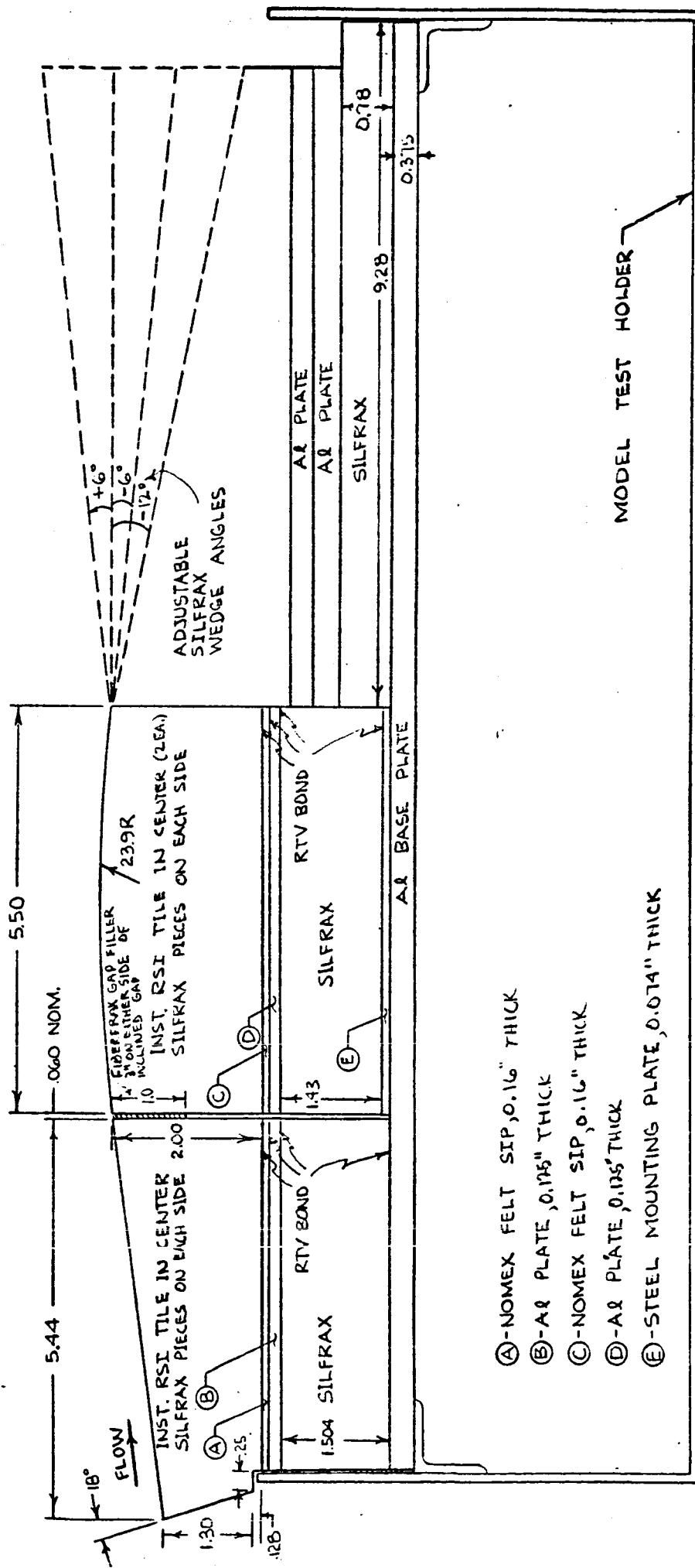
DEPTH (IN.)	TMM NODE NO.	T/C STACK F2				T/C STACK D3		T/C STACK H2	
		RUN 24	RUN 27	RUN 28	RUN 32	RUN 24	TMM NODE NO.	RUNS* 29,30,31,32	
0.025	706	0.550	0.20	0.265	0.300	0.400	705	0.550	
0.075	712	0.120	0.075	0.070	0.038	0.110	711	0.165	
0.125	718	0.085	0.046	0.055	0.032	0.072	717	0.068	
0.175	724	0.075	0.033	0.046	0.028	0.056	723	0.035	
0.250	730	0.065	0.024	0.040	0.026	0.045	729	0.020	
0.400	736	0.055	0.014	0.0315	0.023	0.033	735	0.002	
0.625	742	0.0455	0.0101	0.0225	0.020	0.023	741	0.0	
0.875	748	0.0395	0.0090	0.0185	0.0185	0.017	747	0.0	
1.125	754	0.0325	0.0082	0.0168	0.0165	0.0132	753	0.0	
1.375	760	0.0245	0.0068	0.0135	0.0148	0.0104	759	0.0	
1.625	766	0.0160	0.0056	0.0110	0.0132	0.0083	765	0.0	
1.875	862	0.0085	0.0048	0.0095	0.0118	0.0068	861	0.0	
2.000	796	0.0065	0.0044	0.0085	0.0112	0.0061	795	0.0	

*BASELINE (ZERO PRESSURE GRADIENT) HEATING RATIO

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• Fig.2 SIDE VIEW OF AMES DOUBLE WEDGE MODEL INCL. MODEL TEST HOLDER

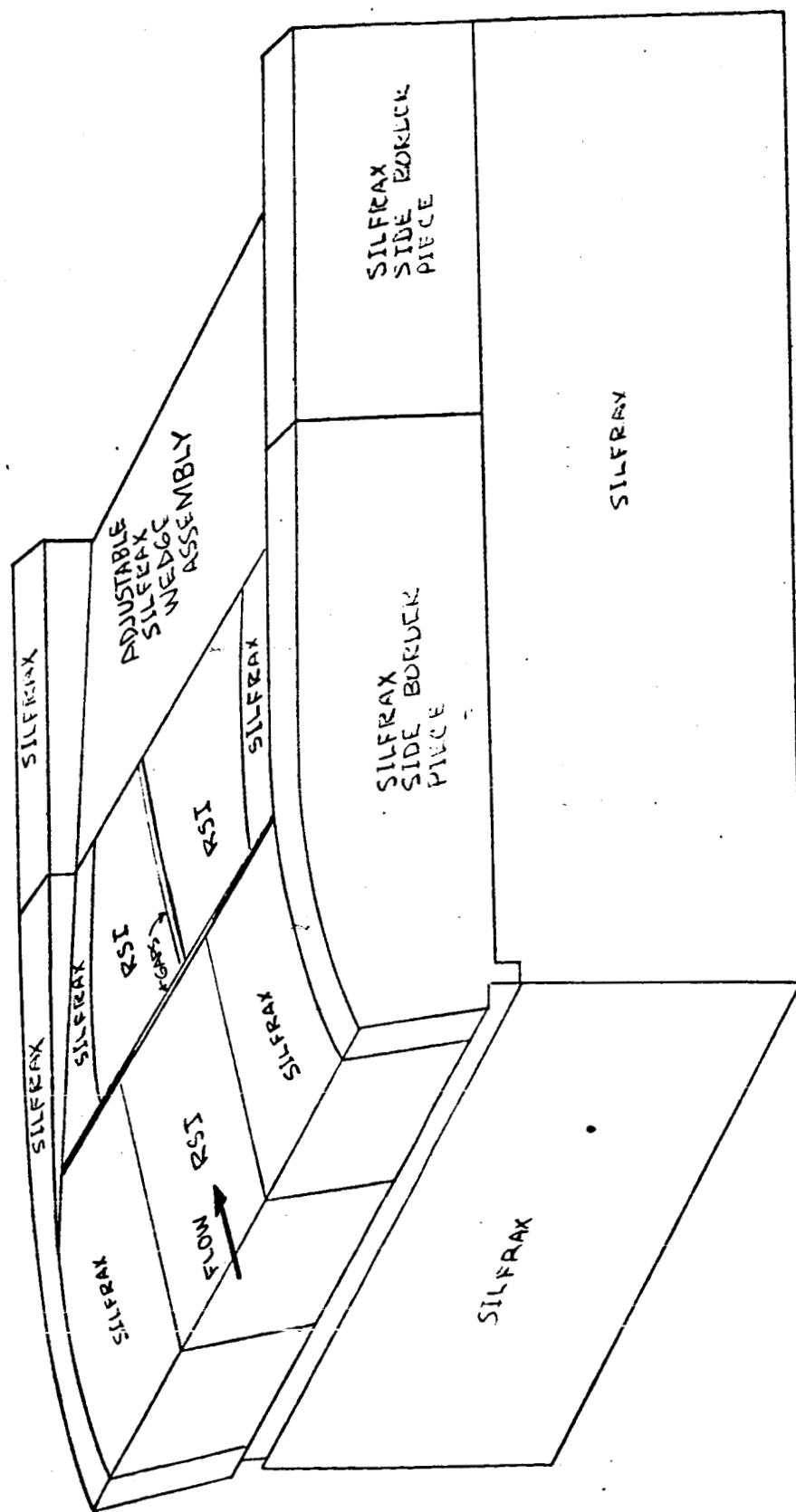
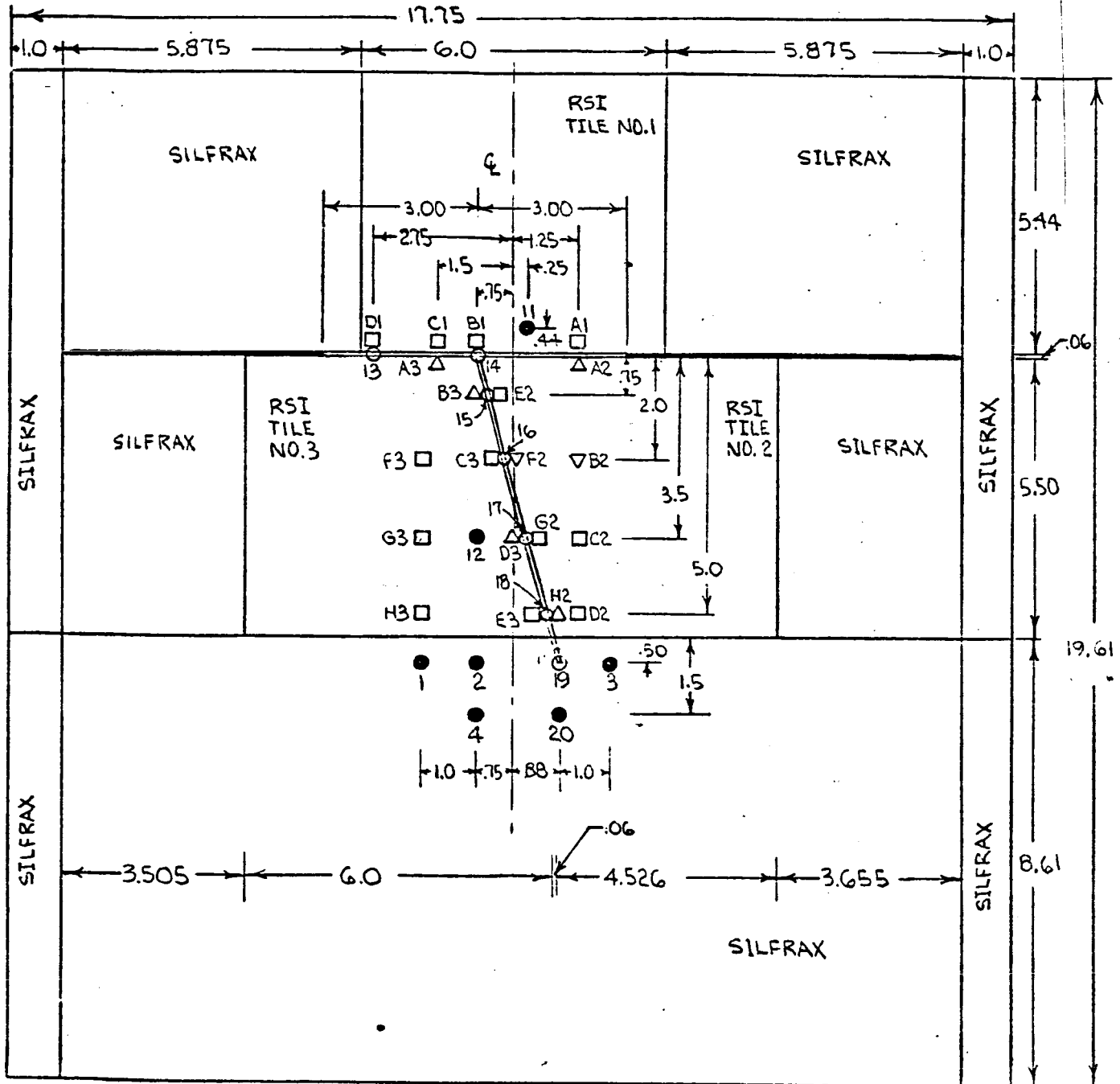


Fig.3 ISOMETRIC VIEW OF AMES DOUBLE WEDGE MODEL

FLOW



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- NOTE:
- SURFACE THERMOCOUPLE ONLY
 - △ IN-DEPTH THERMOCOUPLES ONLY
 - ▽ SURFACE AND IN-DEPTH THERMOCOUPLES
 - SURFACE PRESSURE SENSORS
 - IN-GAP PRESSURE SENSORS
 - T/C'S NEAR GAP MOUNTED $\frac{1}{4}$ " TO $\frac{1}{8}$ " FROM EDGE
 - INSTRUMENTED GAP IS INCLINED 15° TO FLOW DIRECTION

Fig.4 LOCATION OF INSTRUMENTATION ON AMES DOUBLE WEDGE MODEL

FIG. 5 SURFACE AND GAP PRESSURE DISTRIBUTION ALONG ANIES DOUBLE WEDGE MODEL FOR RUN 17 (-6° WEDGE ANGLE, 0.06" GAP WIDTH, COND. 1)

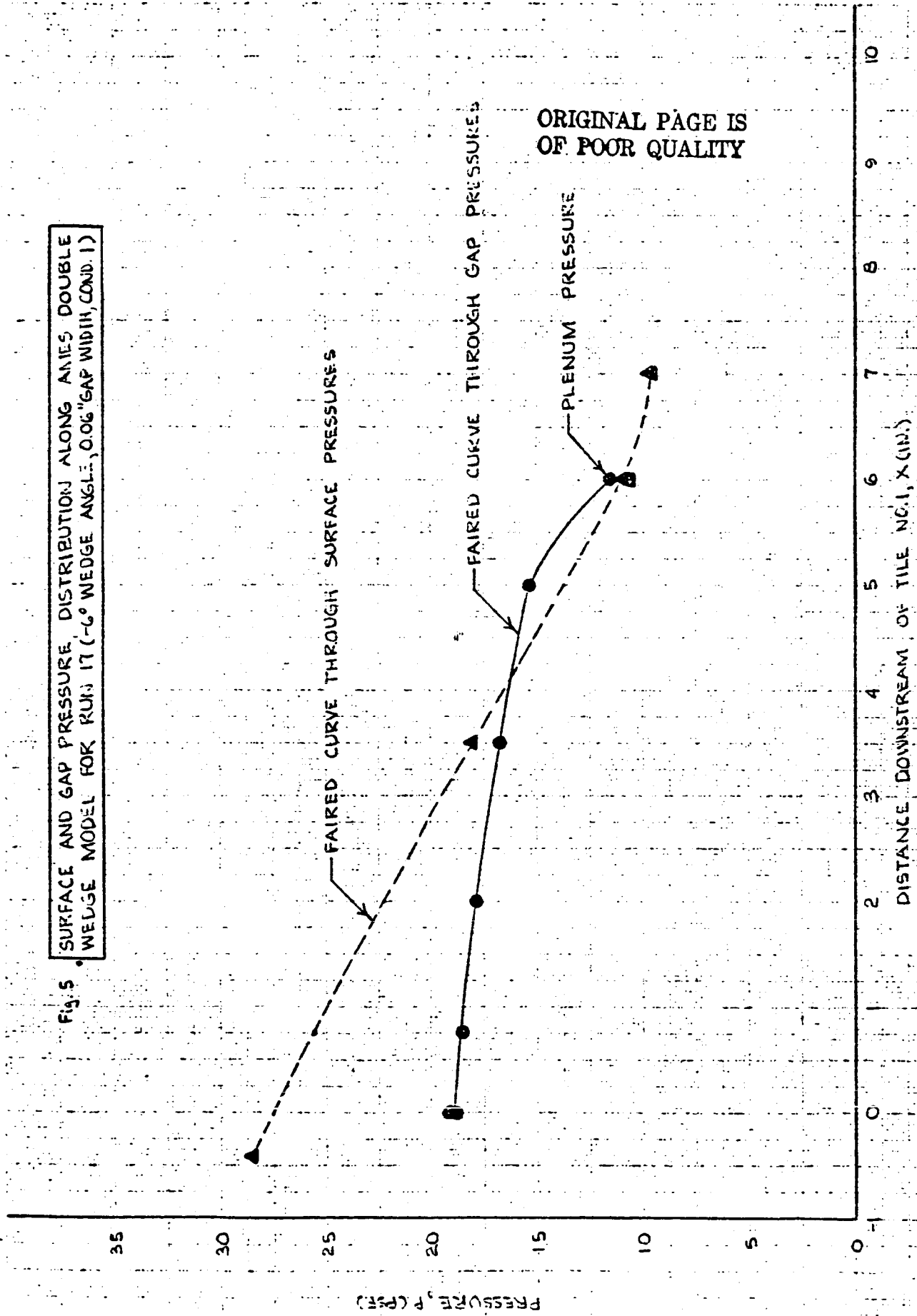


Fig. 6 SURFACE AND GAP PRESSURE DISTRIBUTION ALONG AMIES DOUBLE WEDGE MODEL FOR RUN 20 (-6° WEDGE ANGLE, 0.06° GAP WIDTH, COND. $1\frac{1}{2}$)

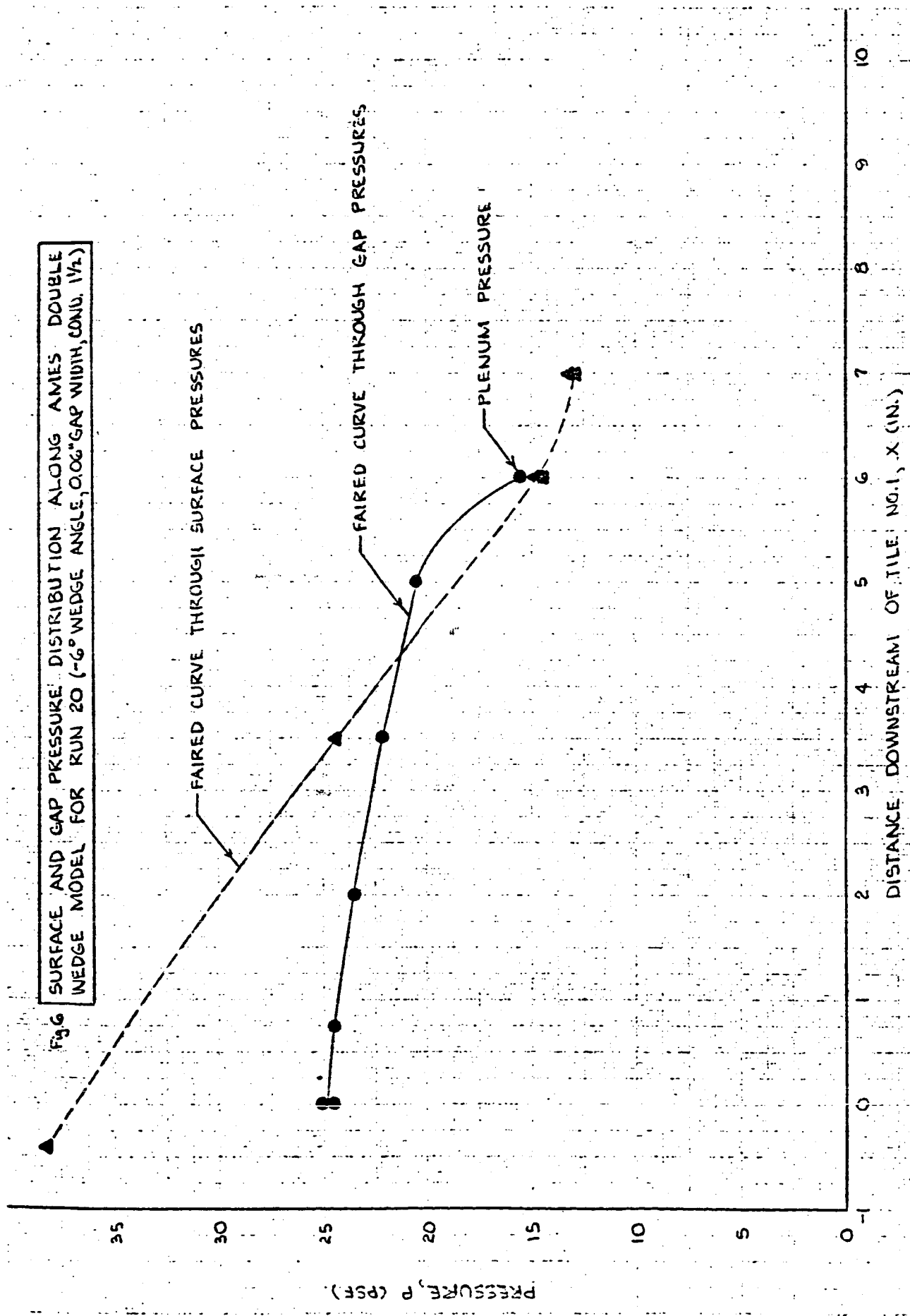
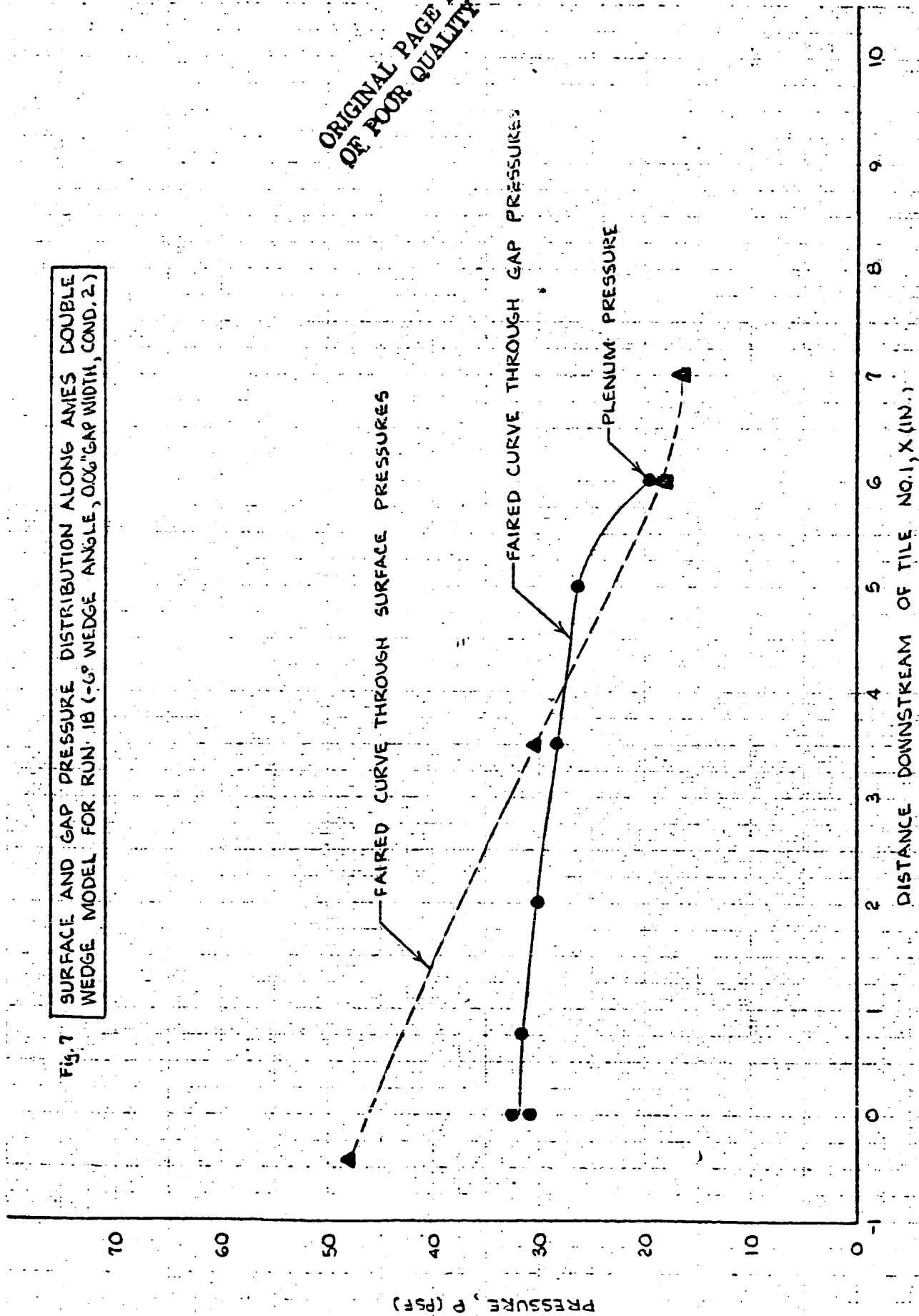


Fig. 7 SURFACE AND GAP PRESSURE DISTRIBUTION ALONG AMES DOUBLE WEDGE MODEL FOR RUN 1B (-3° WEDGE ANGLE, 0.06" GAP WIDTH, COND. 2)



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Fig. 8
SURFACE AND GAP PRESSURE DISTRIBUTION ALONG AMES DOUBLE
WEDGE MODEL FOR RUN 22 (0° WEDGE ANGLE, 0.06" WEDGE ANGLE, COND. 1)

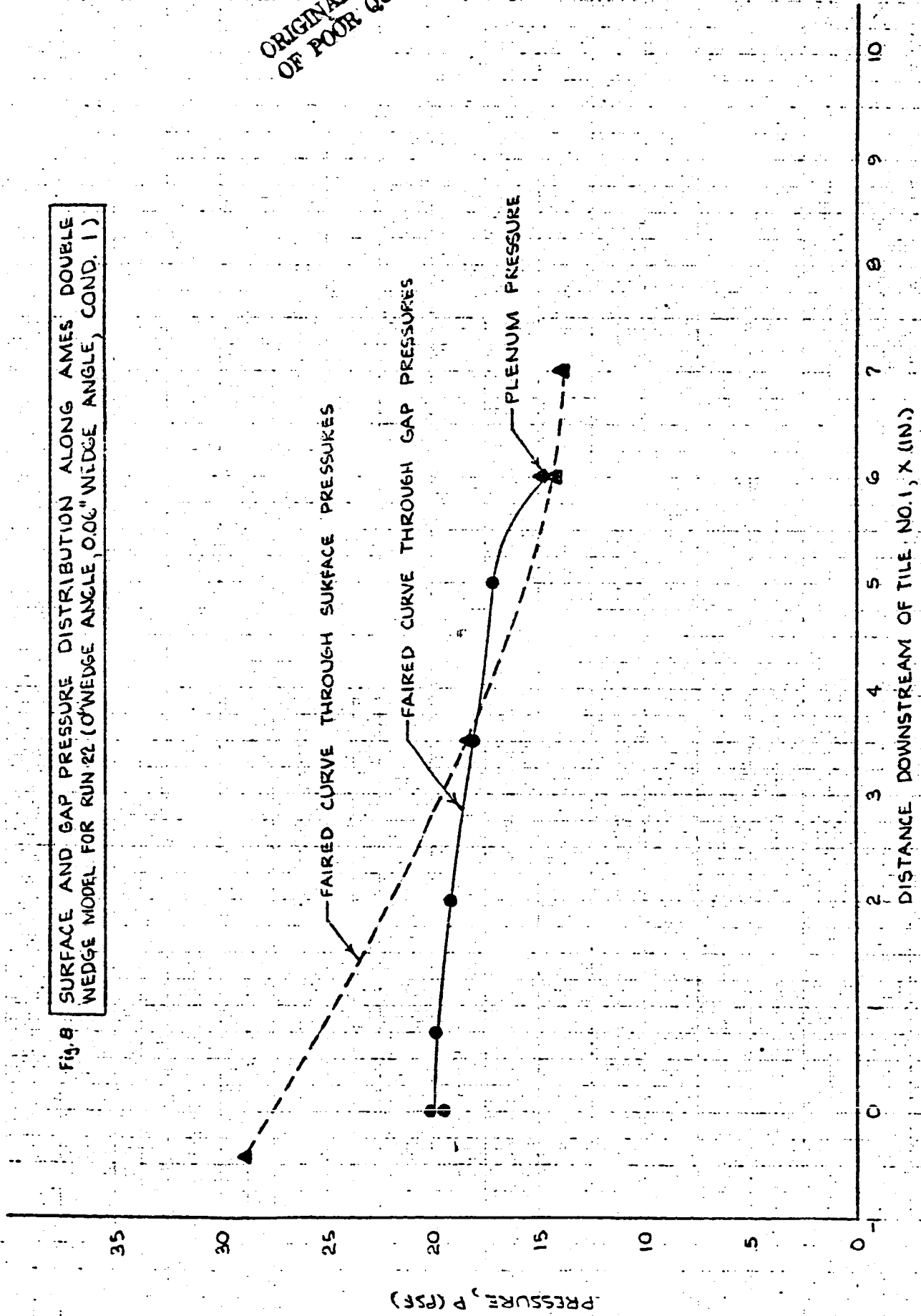
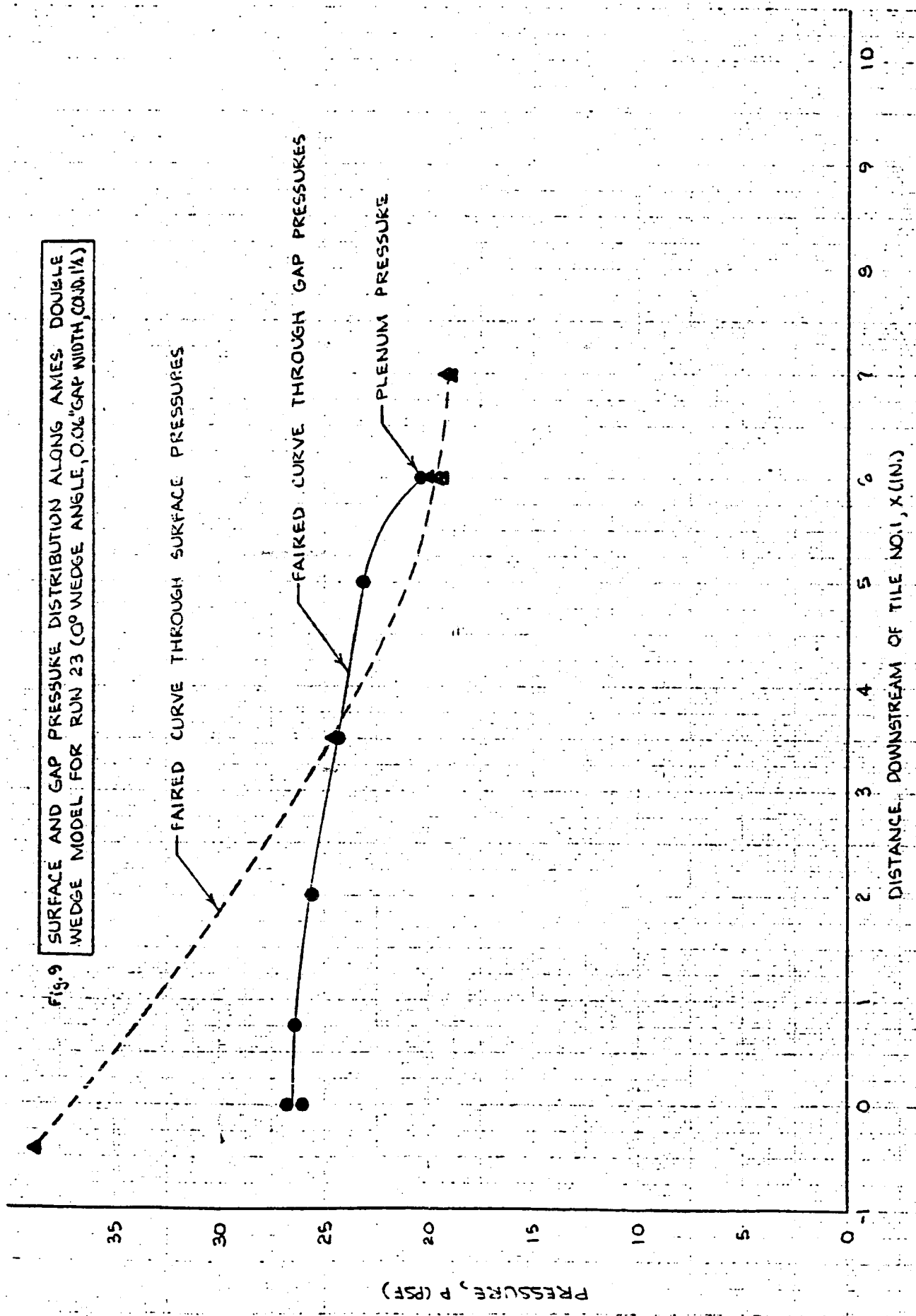


Fig. 9 SURFACE AND GAP PRESSURE DISTRIBUTION ALONG AMES DOUBLE WEDGE MODEL FOR RUN 23 (0° WEDGE ANGLE, 0.02" GAP WIDTH, CO₂ 1/4)



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FIG. 10 SURFACE AND GAP PRESSURE DISTRIBUTION ALONG AMES DOUBLE
WEDGE MODEL FOR RUN 24 (0° WEDGE ANGLE, 0.06" GAP WIDTH, COND. 2)

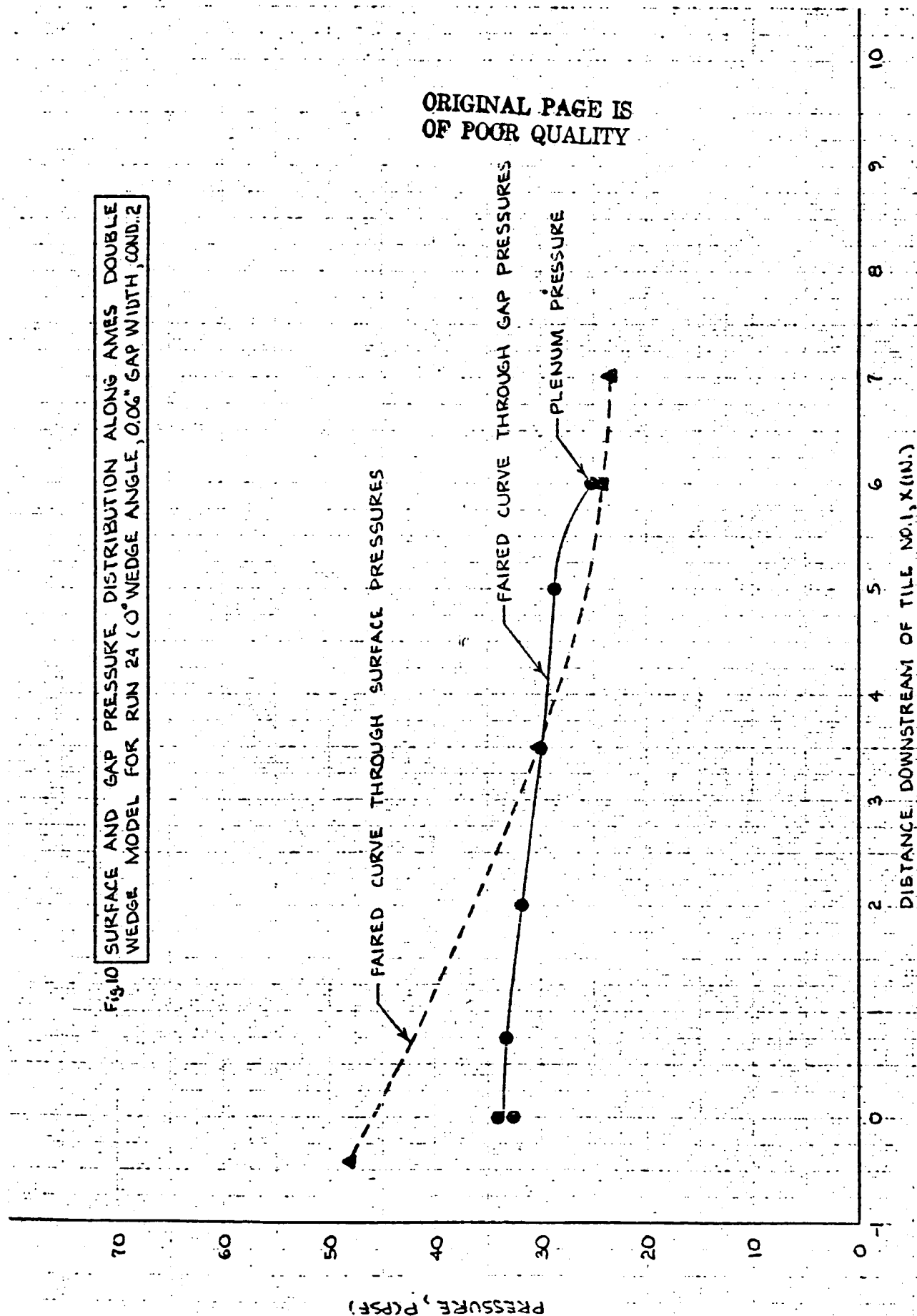
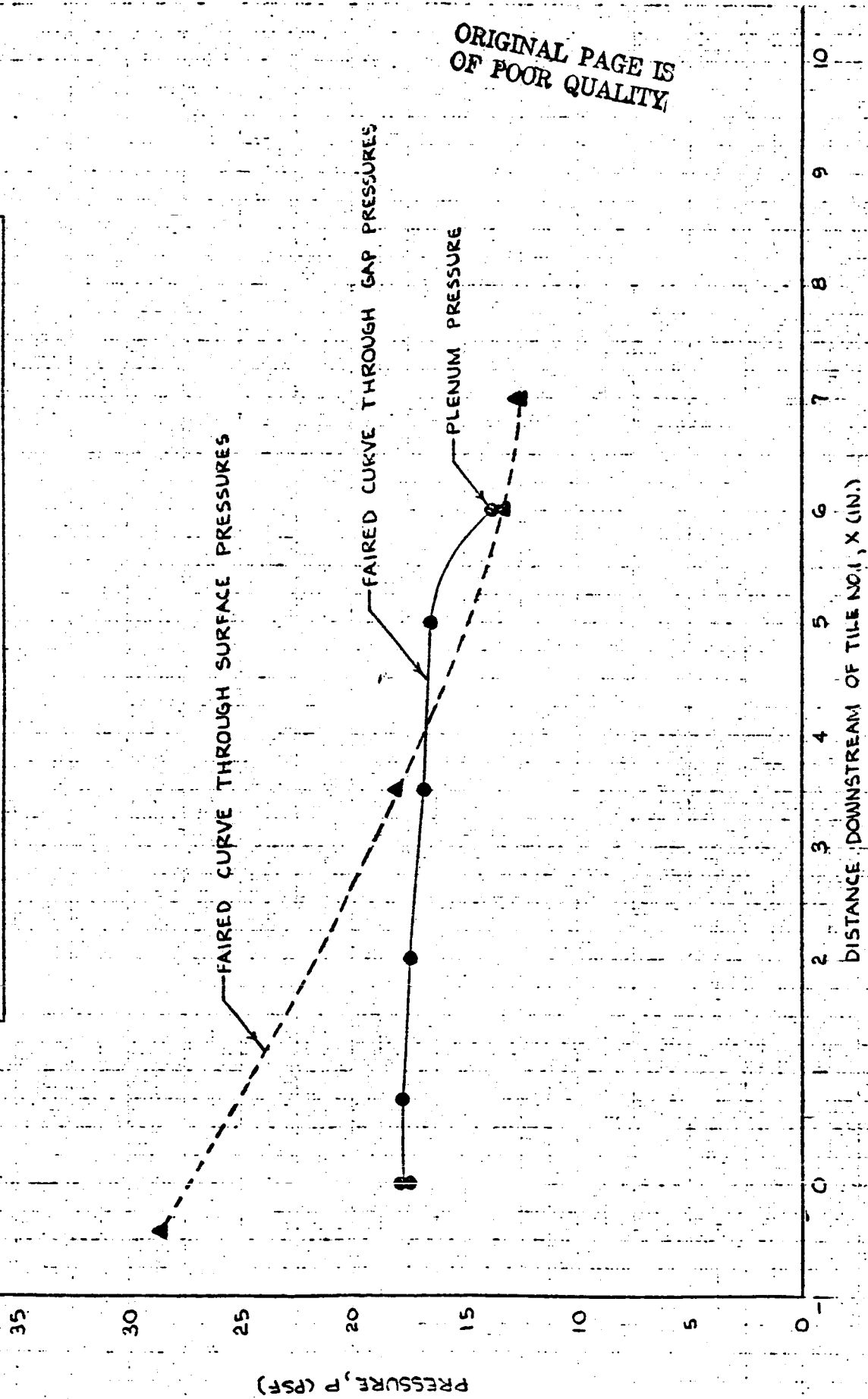


FIG. 11 SURFACE AND GAP PRESSURE DISTRIBUTION ALONG AMES DOUBLE WEDGE MODEL FOR RUN 25 (0° WEDGE ANGLE, 0.03" GAP WIDTH, COND. 1)



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FIG. 12 SURFACE AND GAP PRESSURE DISTRIBUTION ALONG AMES DOUBLE
WEDGE MODEL FOR RUN 26 (0° WEDGE ANGLE, 0.63" GAP WIDTH, COND. 1/2)

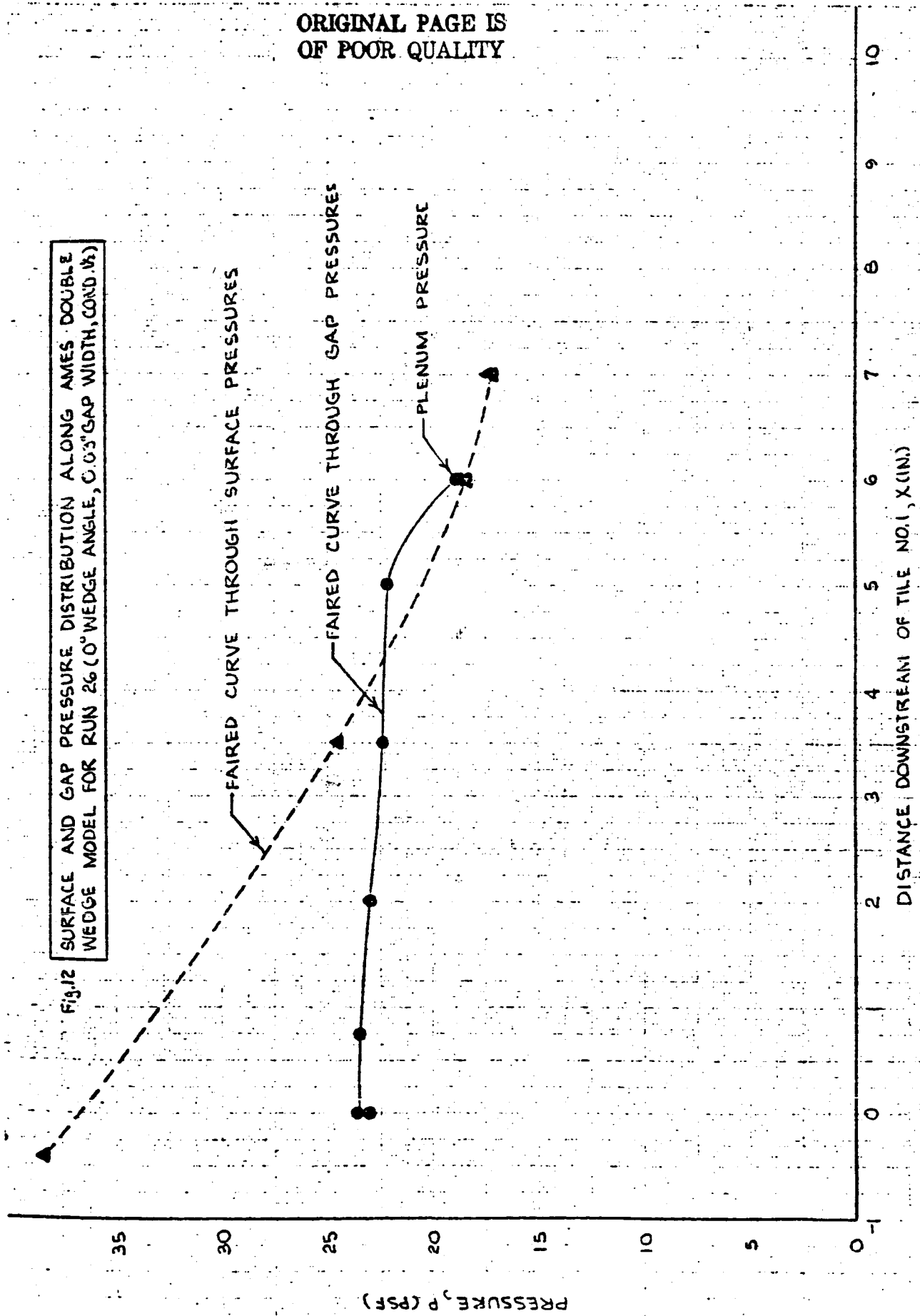


Fig. 13 SURFACE AND GAP PRESSURE DISTRIBUTION ALONG AMES DOUBLE WEDGE MODEL FOR RUN 27 (0° WEDGE ANGLE, 0.03" GAP WIDTH, COND. 2)

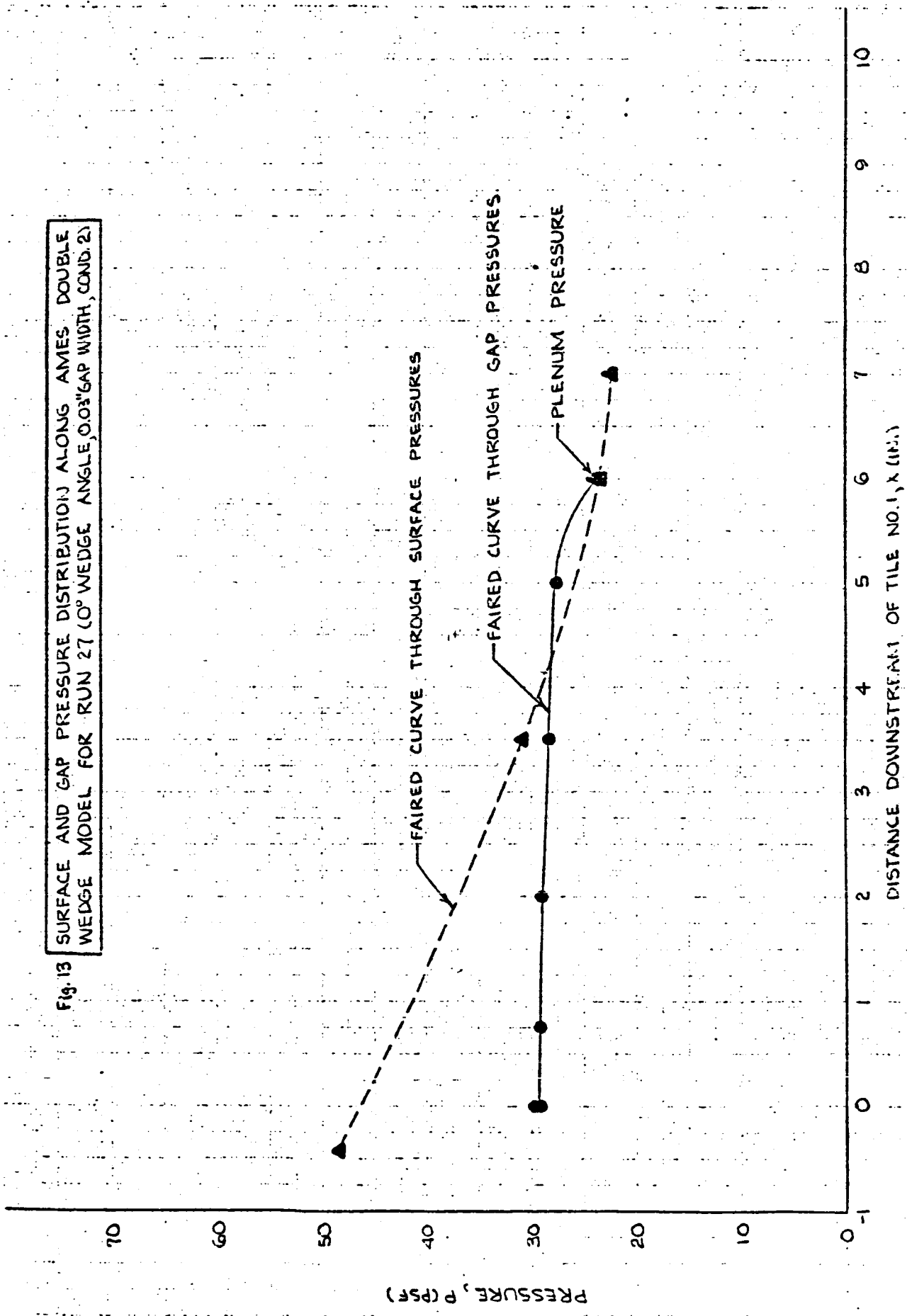
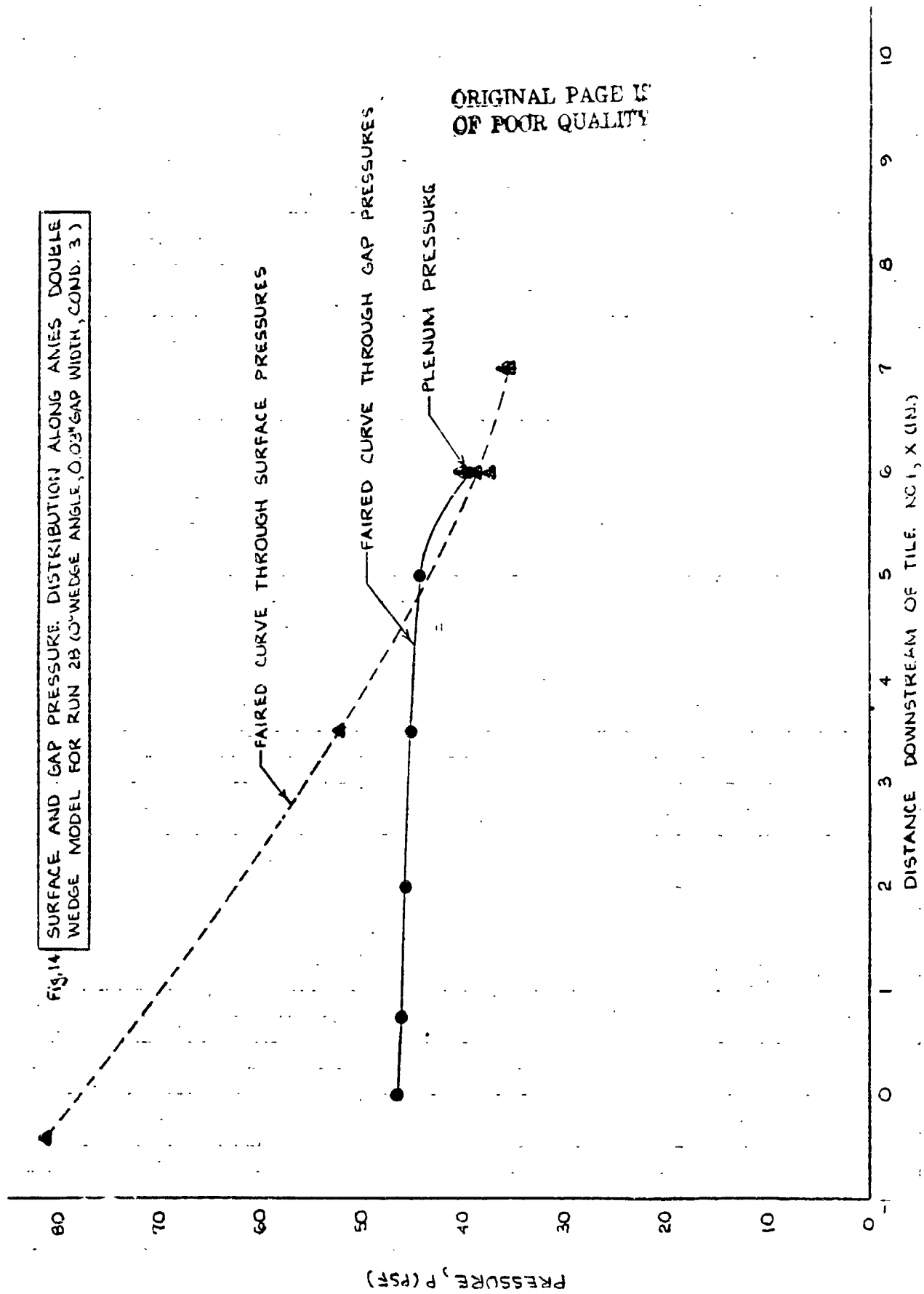


FIG. 14 SURFACE AND GAP PRESSURE DISTRIBUTION ALONG ANES DOUBLE WEDGE MODEL FOR RUN 2B (3° WEDGE ANGLE, 0.03" GAP WIDTH, COND. 3)



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Fig. 15 SURFACE AND GAP PRESSURE DISTRIBUTION ALONG AMES DOUBLE
WEDGE MODEL FOR KUN 29(-6° WEDGE ANGLE, 0.03" GAP WIDTH, COND. 1)

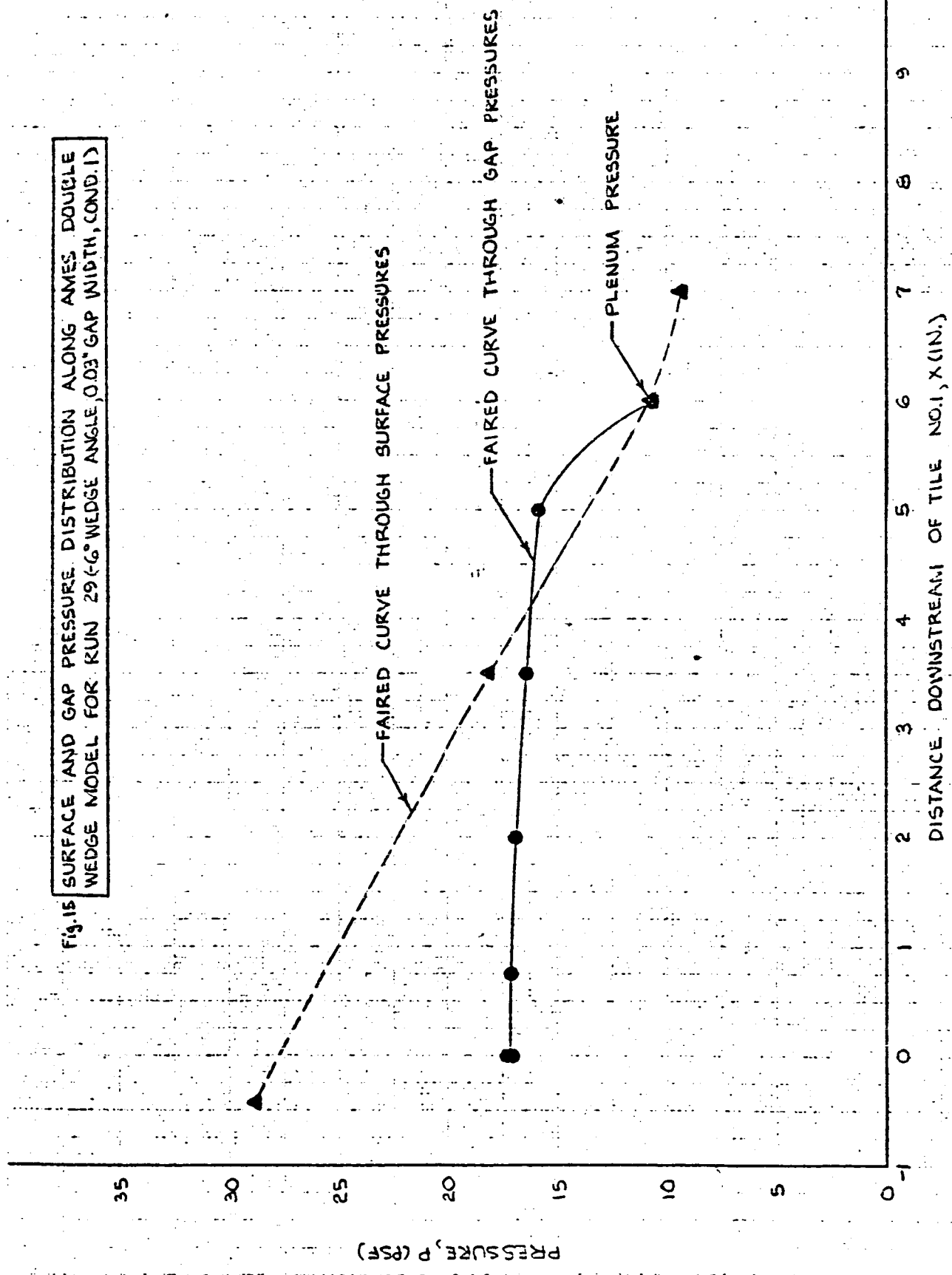


FIG. 6 SURFACE AND GAP PRESSURE DISTRIBUTION ALONG AMES DOUBLE WEDGE MODEL FOR RUN 30 (6° WEDGE ANGLE, 0.03" GAP WIDTH, COND. 1½)

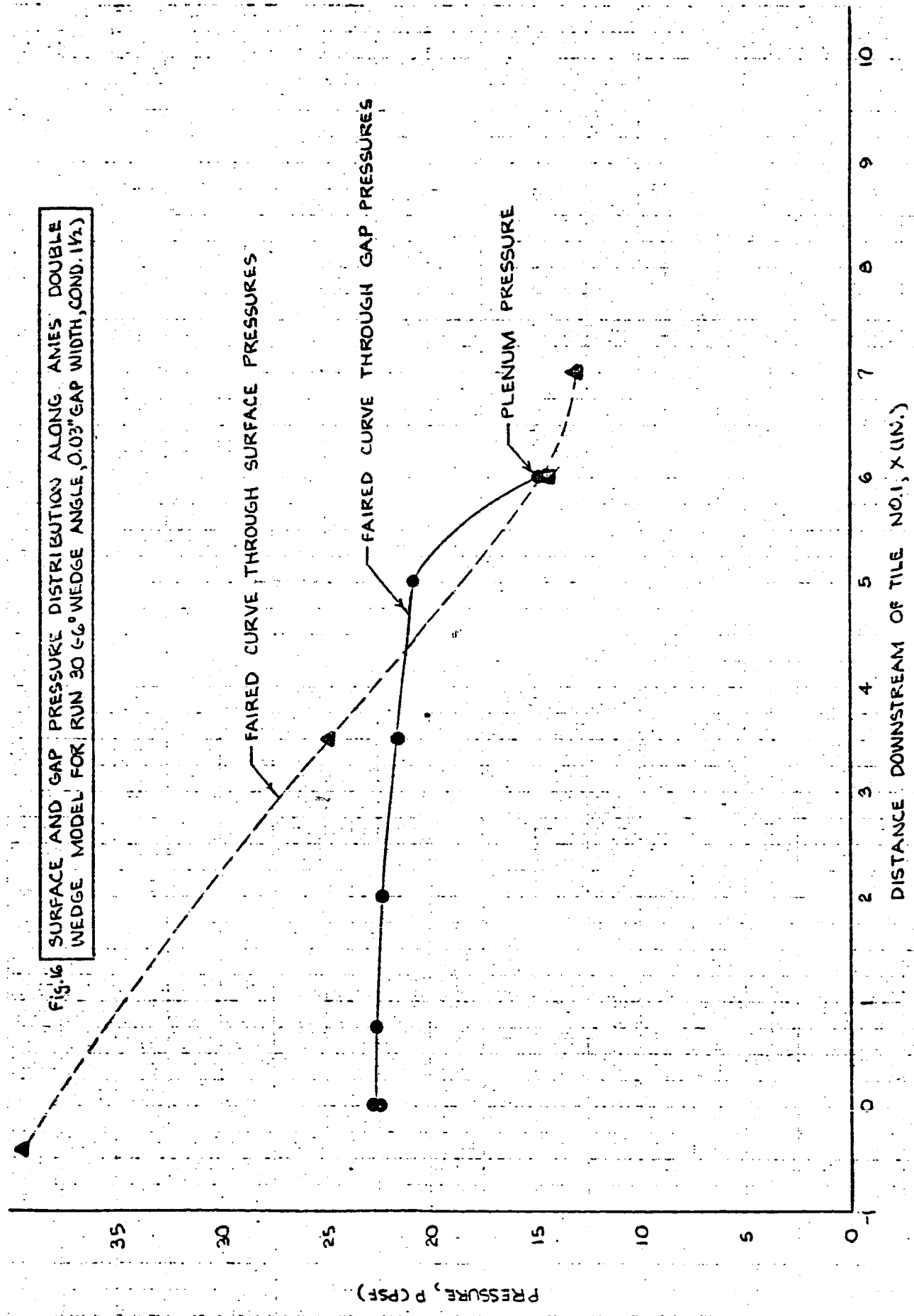
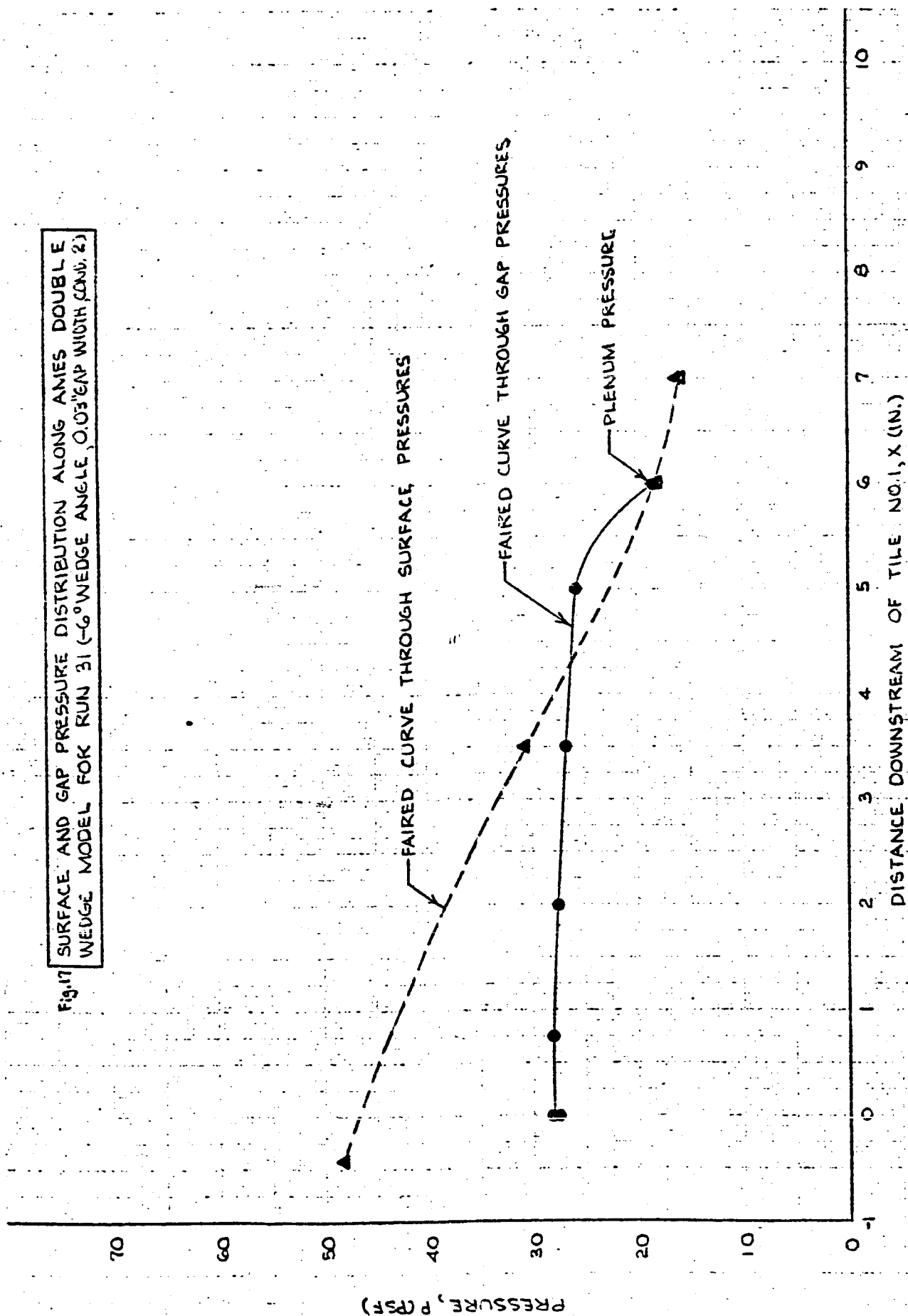


Fig. 17 SURFACE AND GAP PRESSURE DISTRIBUTION ALONG ANIES DOUBLE WEDGE MODEL FOR RUN 31 (-6° WEDGE ANGLE, 0.03" GAP WIDTH COND. 2)



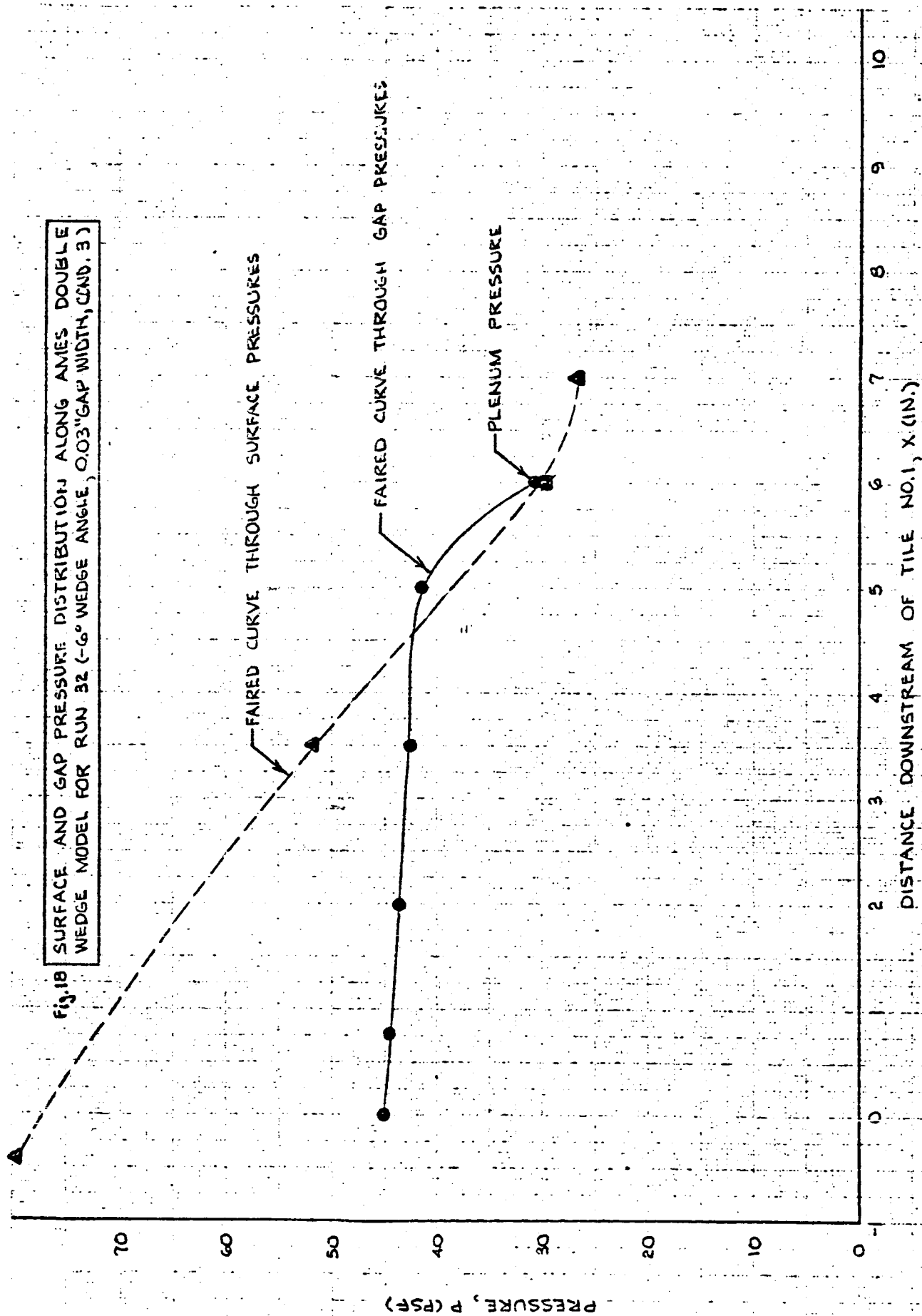


Fig. 18A

COMPARISON OF SURFACE AND GAP PRESSURES FOR AMES DOUBLE WEDGE MODEL FOR 0.03 IN. GAP WIDTH AND 0° WEDGE ANGLE

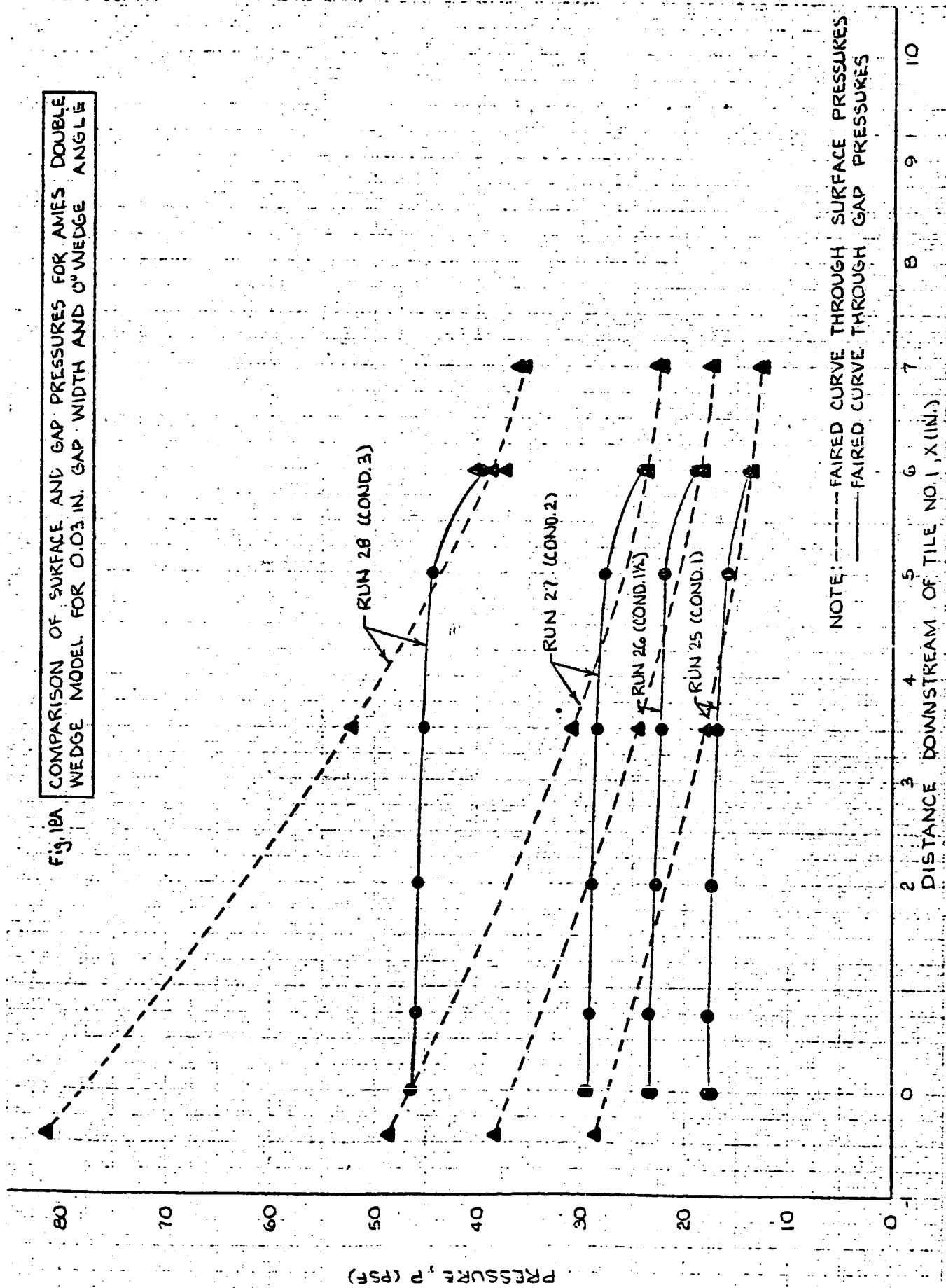


Fig. 19 SURFACE TEMPERATURE AS A FUNCTION OF UPSTREAM PRESSURE, P_1 , FOR RUNS 17, 20, & 18 (GAP WIDTH = 0.006", WEDGE ANGLE = -6°)

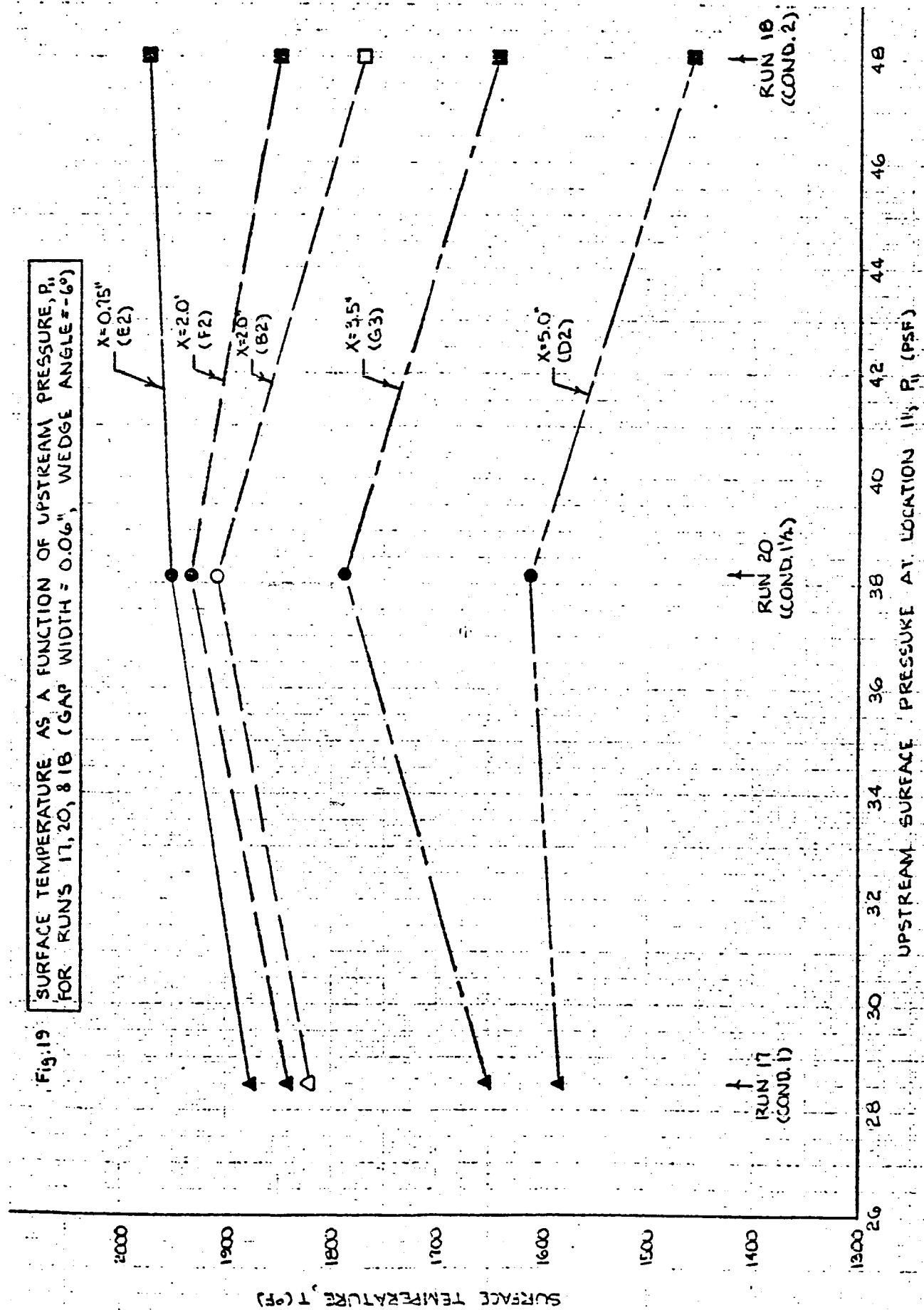


Fig. 20 SURFACE TEMPERATURE AS A FUNCTION OF UPSTREAM PRESSURE, P_1 , FOR RUNS 22, 23, & 24 (GAP WIDTH = 0.06", WEDGE ANGLE = 0°)

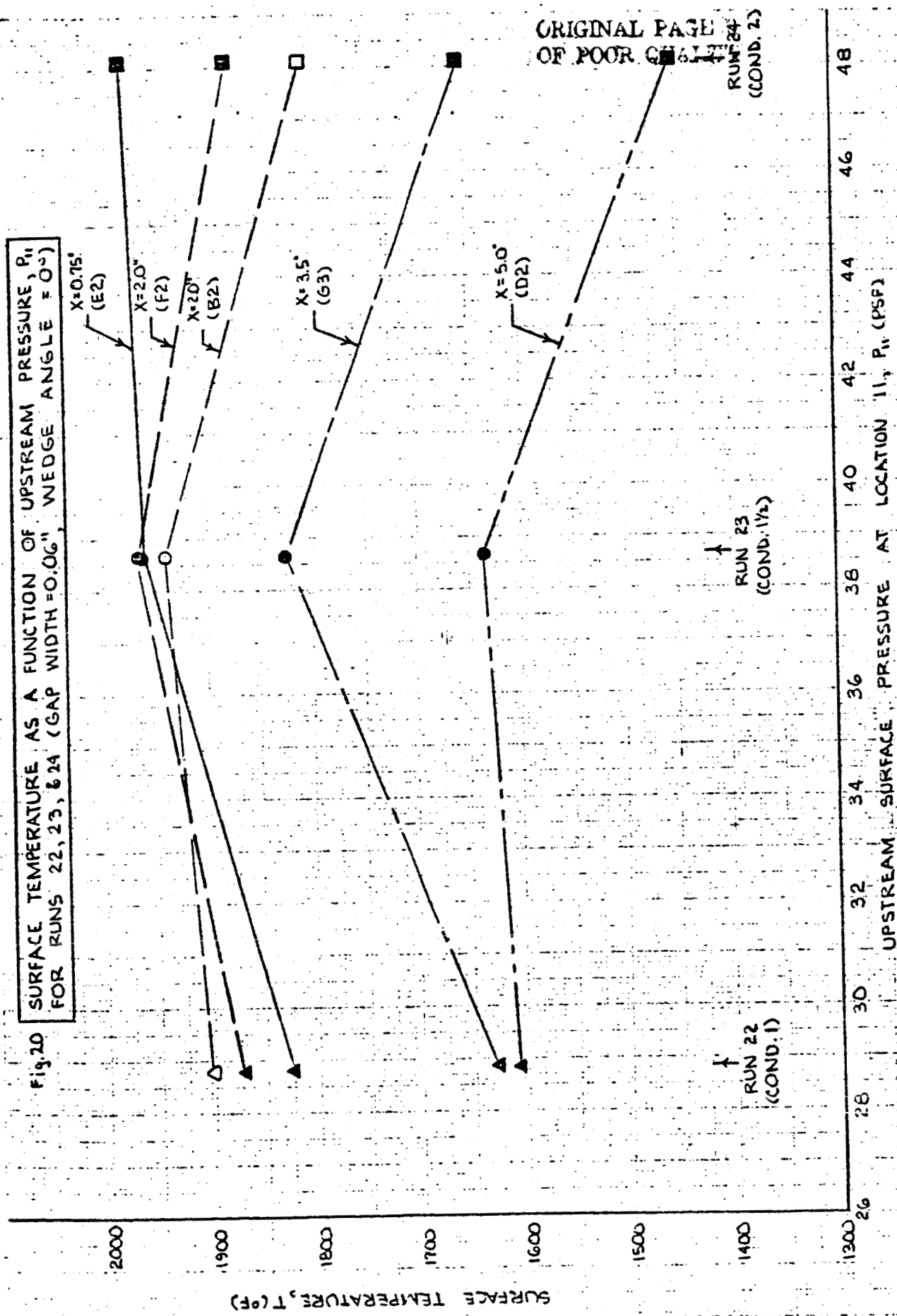


Fig. 21 SURFACE TEMPERATURE AS A FUNCTION OF UPSTREAM PRESSURE, P_1 , FOR RUNS 25, 26, 27, & 28 (GAP WIDTH = 0.03", WEDGE ANGLE = 0.0")

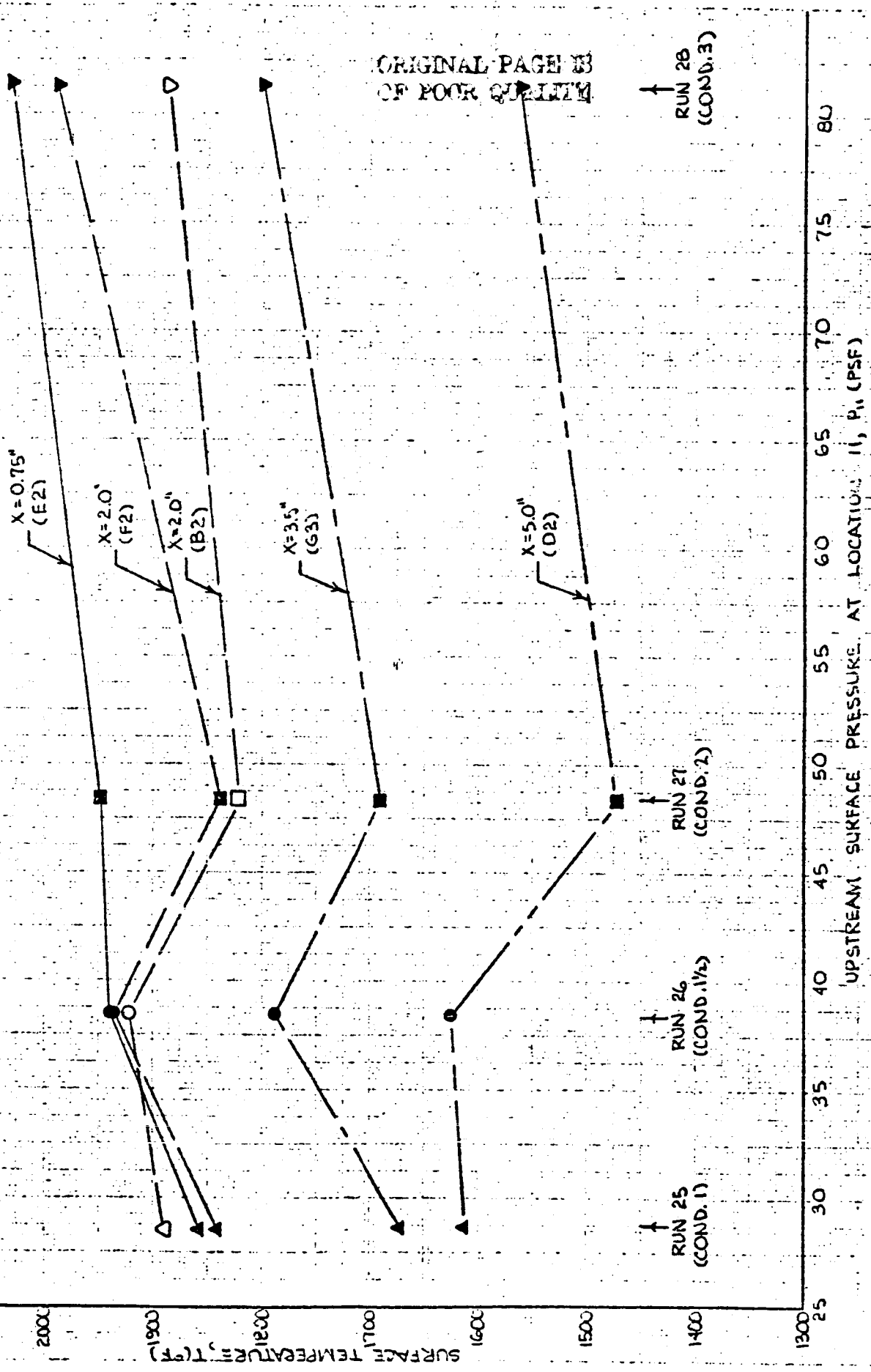


Fig. 22 SURFACE TEMPERATURE AS A FUNCTION OF UPSTREAM PRESSURE, P_{11} FOR RUNS 29, 30, 31, & 32 (GAP WIDTH = 0.03", WEDGE ANGLE = -6°)

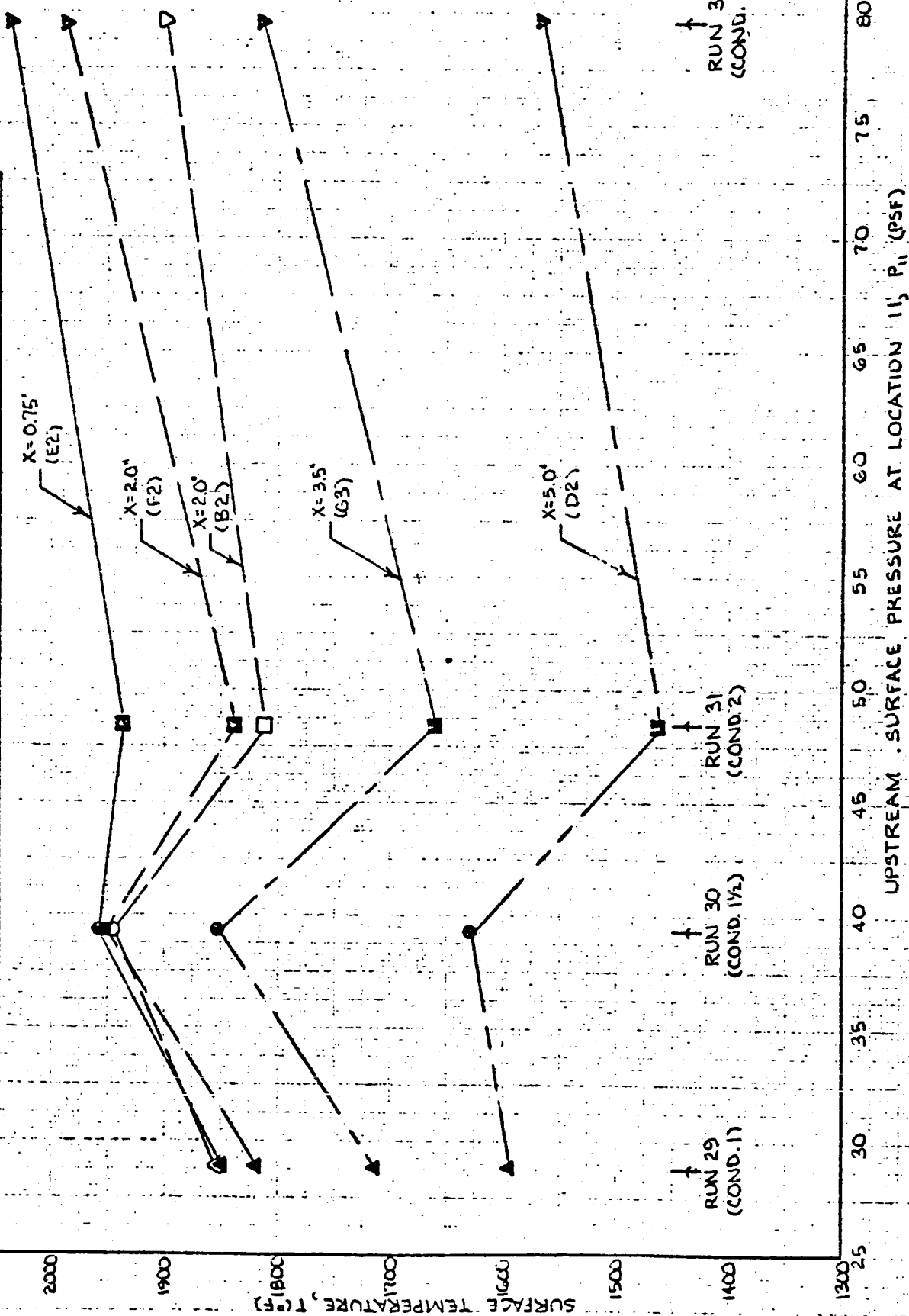
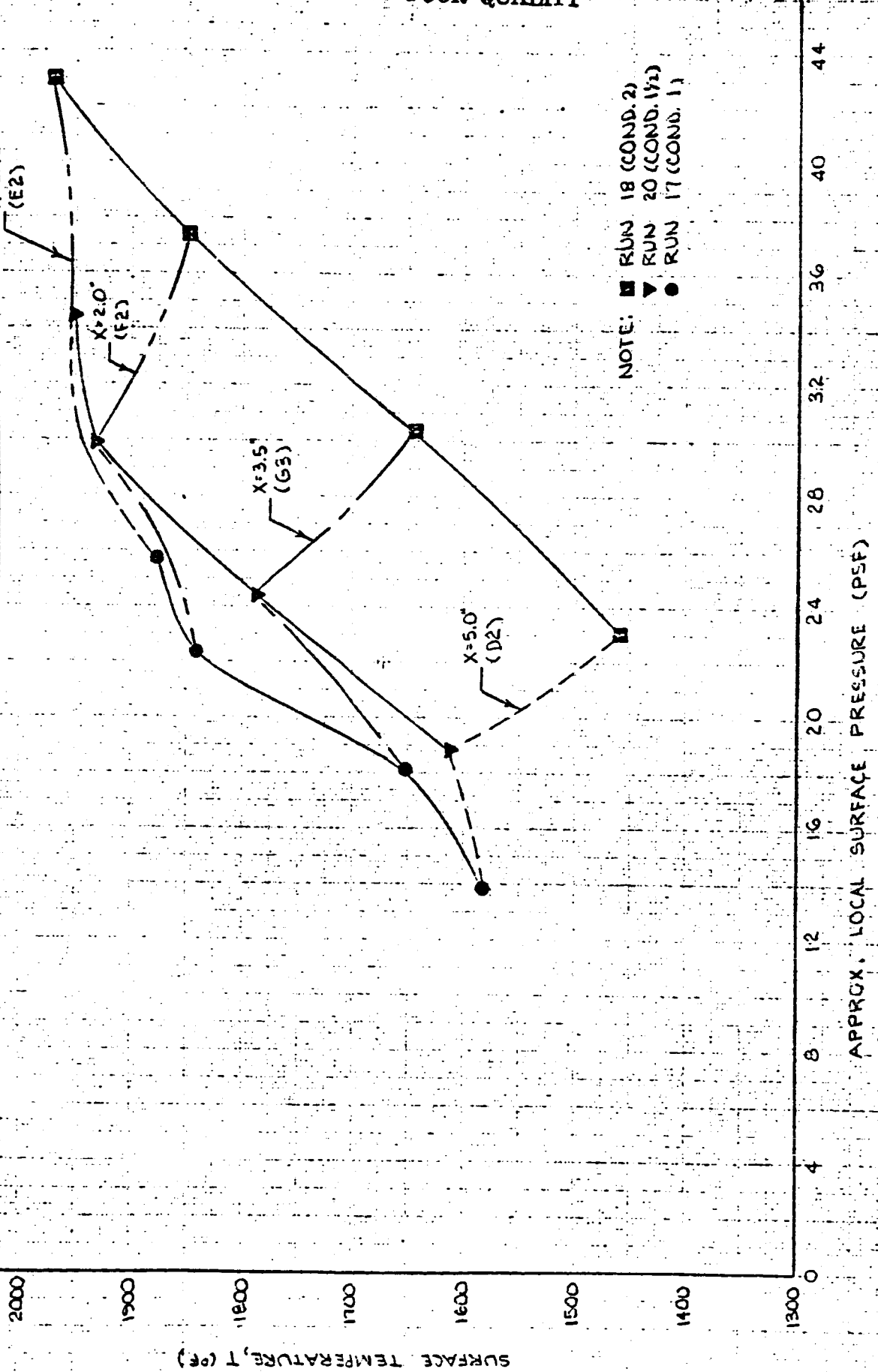


FIG. 23 SURFACE TEMPERATURE AS A FUNCTION OF LOCAL PRESSURE
FOR RUNS 17, 20, & 18 (GAP WIDTH = 0.06", WEDGE ANGLE = -6°)

FIG. 23



NOTE: ■ RUN 18 (COND. 2)
▼ RUN 20 (COND. 1/2)
● RUN 17 (COND. 1)

Fig. 24 SURFACE TEMPERATURE AS A FUNCTION OF LOCAL PRESSURE FOR RUNS 22, 23, & 24 (GAP WIDTH = 0.06", WEDGE ANGLE = 0")

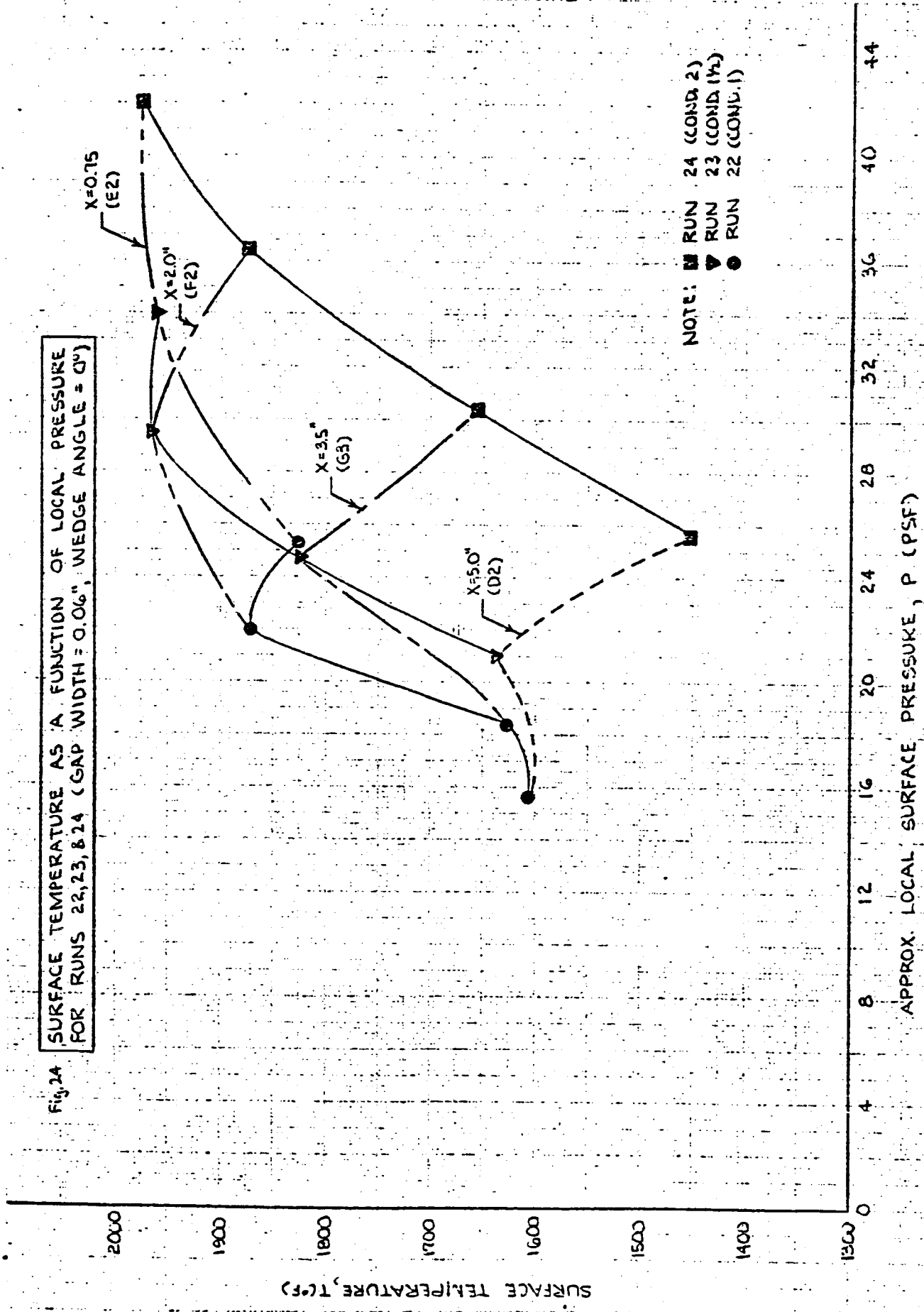
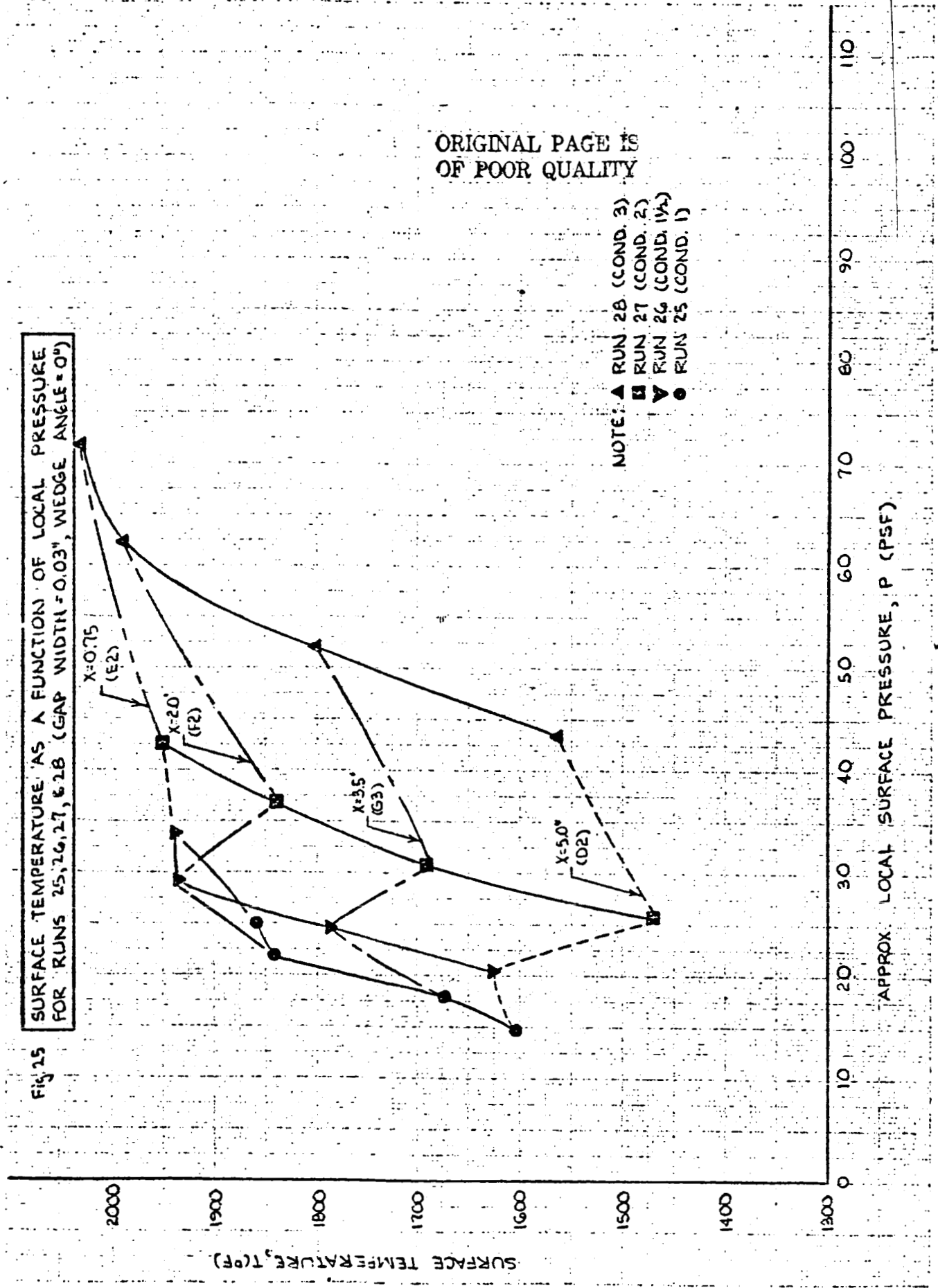
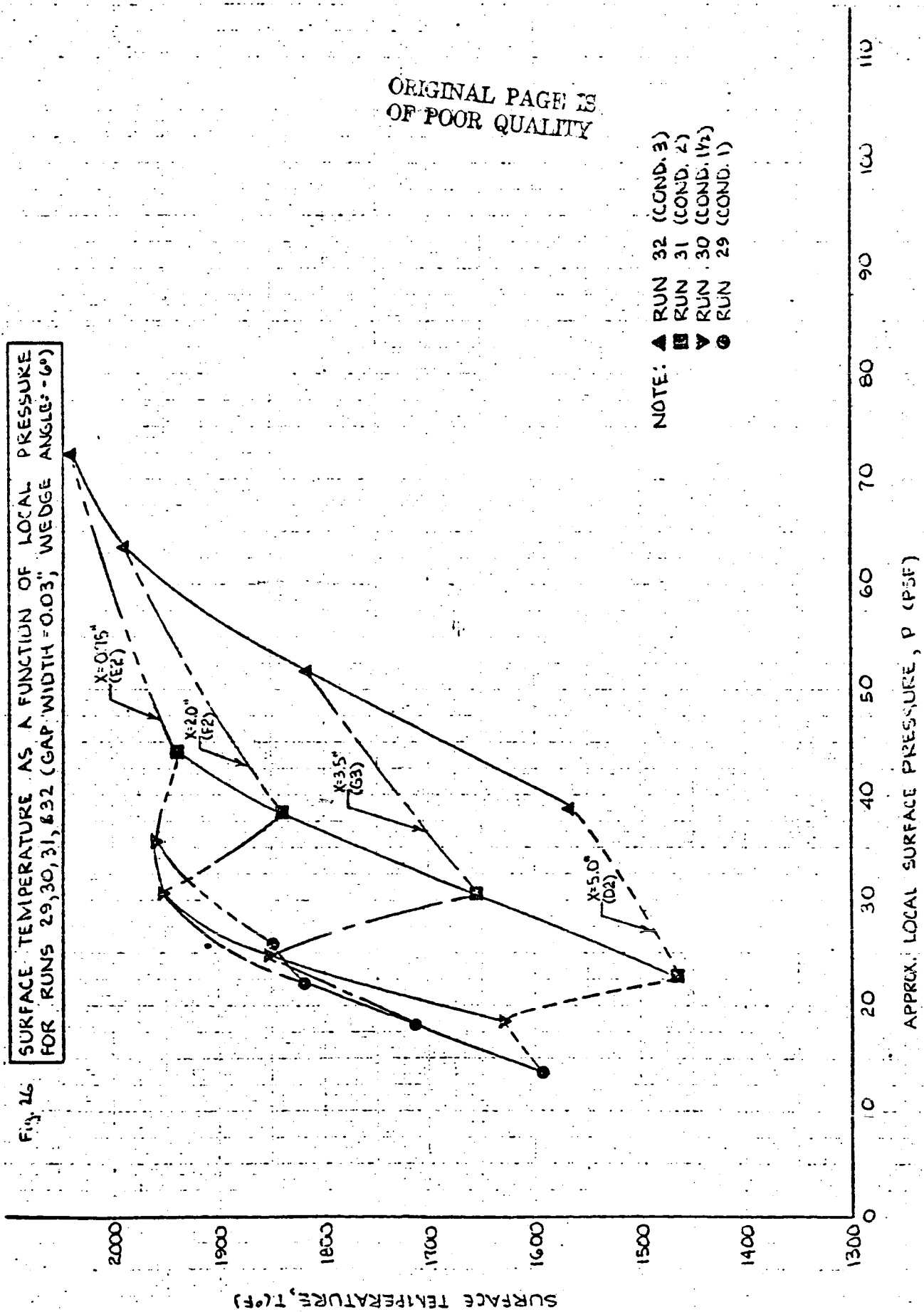


Fig. 15 SURFACE TEMPERATURE AS A FUNCTION OF LOCAL PRESSURE FOR RUNS 25, 26, 27, & 28 (GAP WIDTH = 0.03", WEDGE ANGLE = 0°)



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Fig. 16
SURFACE TEMPERATURE AS A FUNCTION OF LOCAL PRESSURE
FOR RUNS 29, 30, 31, & 32 (GAP WIDTH = 0.03", WEDGE ANGLE = 6°)



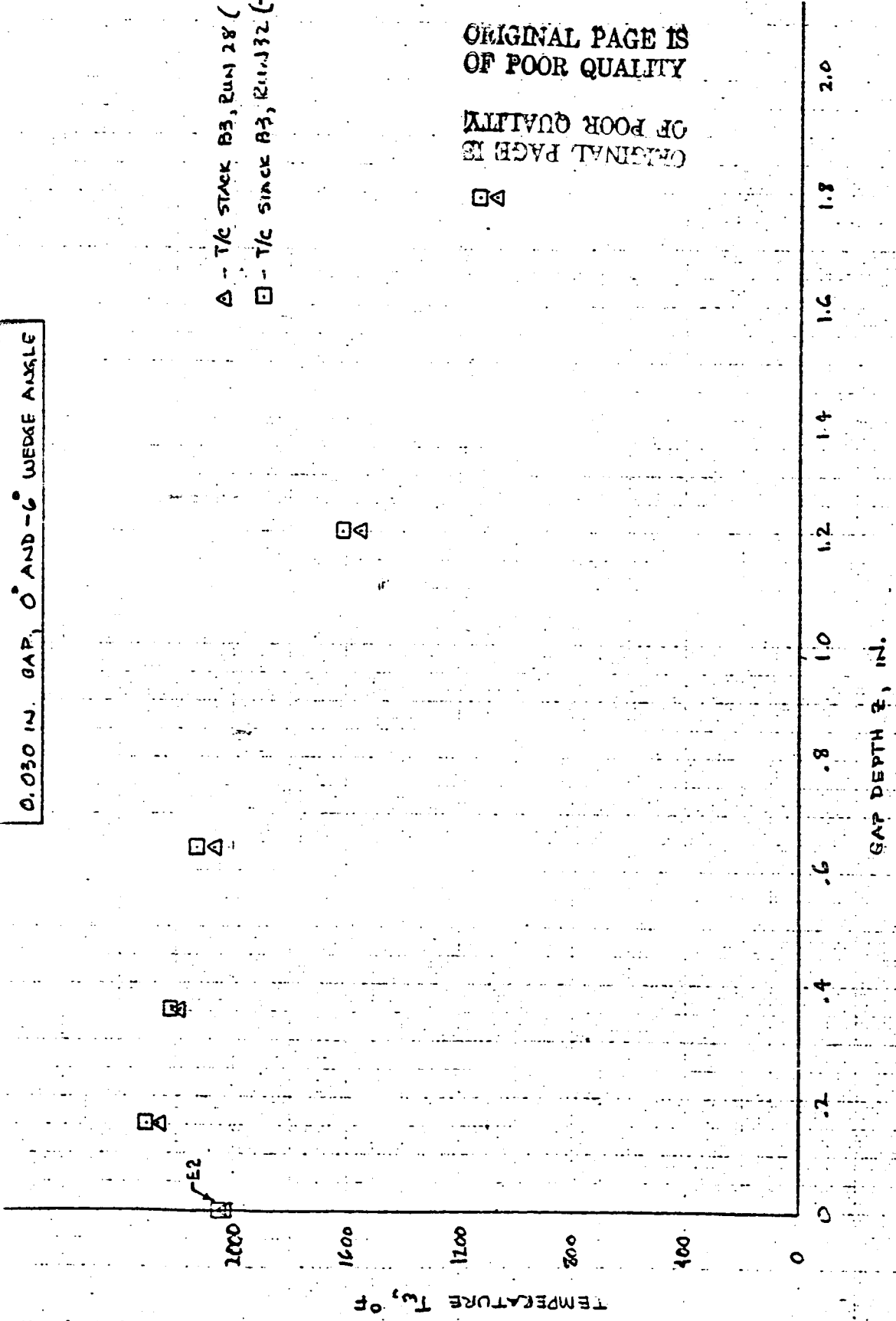
0.030 IN. GAP, 0° AND -6° WEDGE ANGLE

0.030 IN. GAP, 0° AND -6° WEDGE ANGLE

Δ - T/C STACK B3, RUN 28 (0° X)
 □ - T/C STACK B3, RUN 32 (-6° X)

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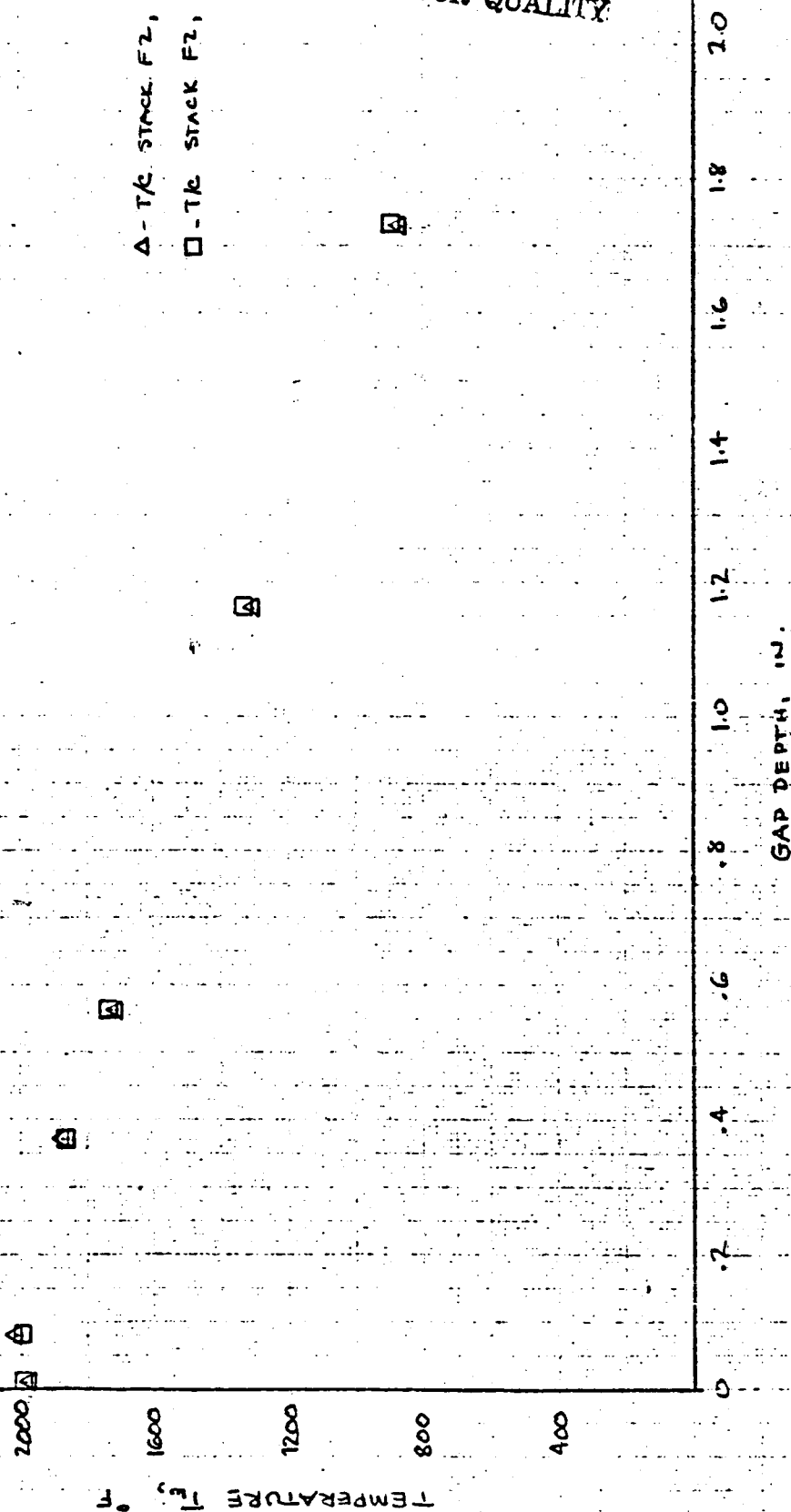
▽



GAP DEPTH, IN.

AMES DOUBLE WEDGE TEST DATA
0.030 IN GAP, 0° AND -6° WEDGE ANGLE

Fig. 28



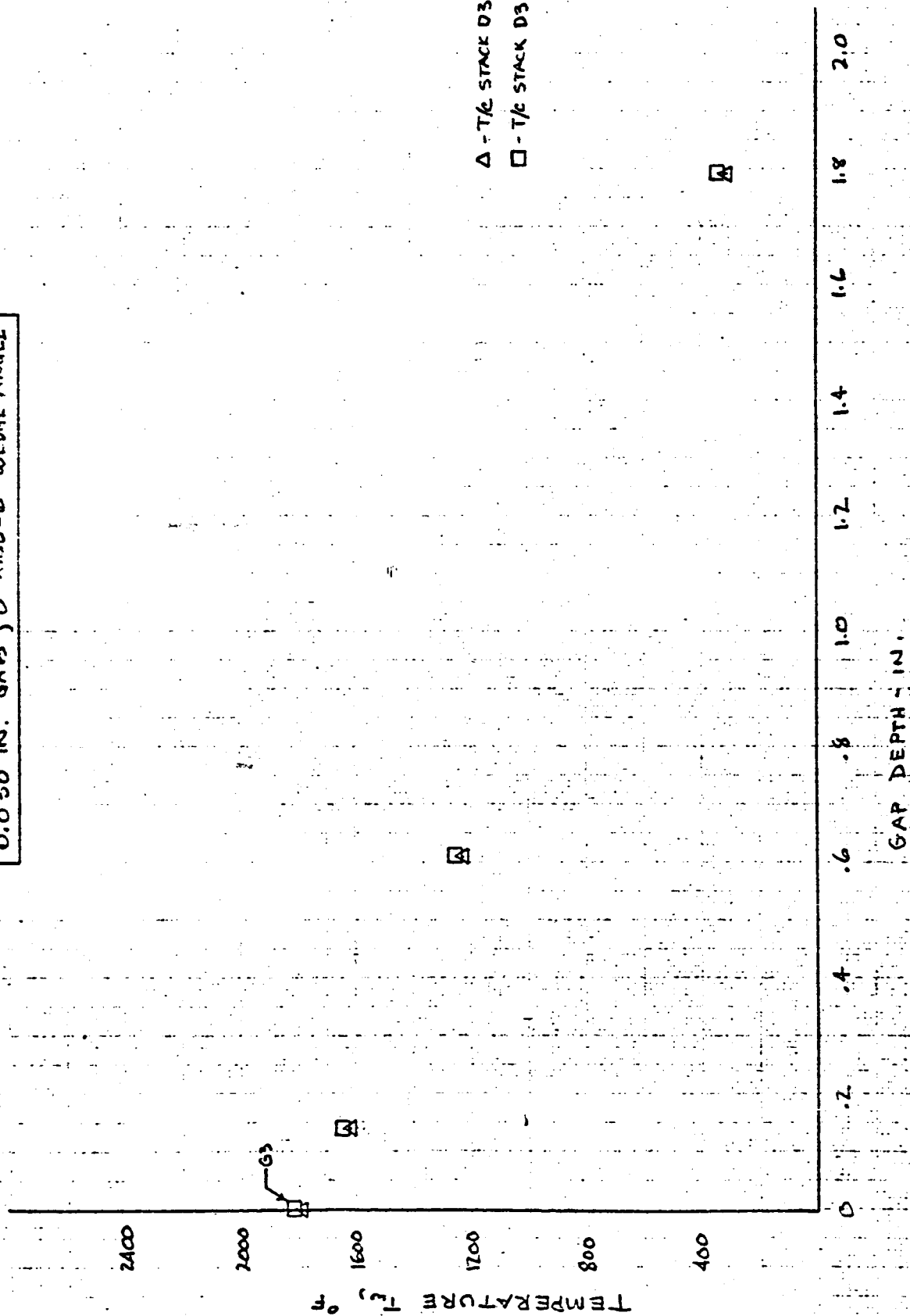
Δ-T/c Stack F2, Run 28 (0°)

□-T/c Stack F2, Run 32 (-6°)

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AMES DOUBLE WEDGE TEST DATA
0.030 IN. GAPS, 0° AND -6° WEDGE ANGLE

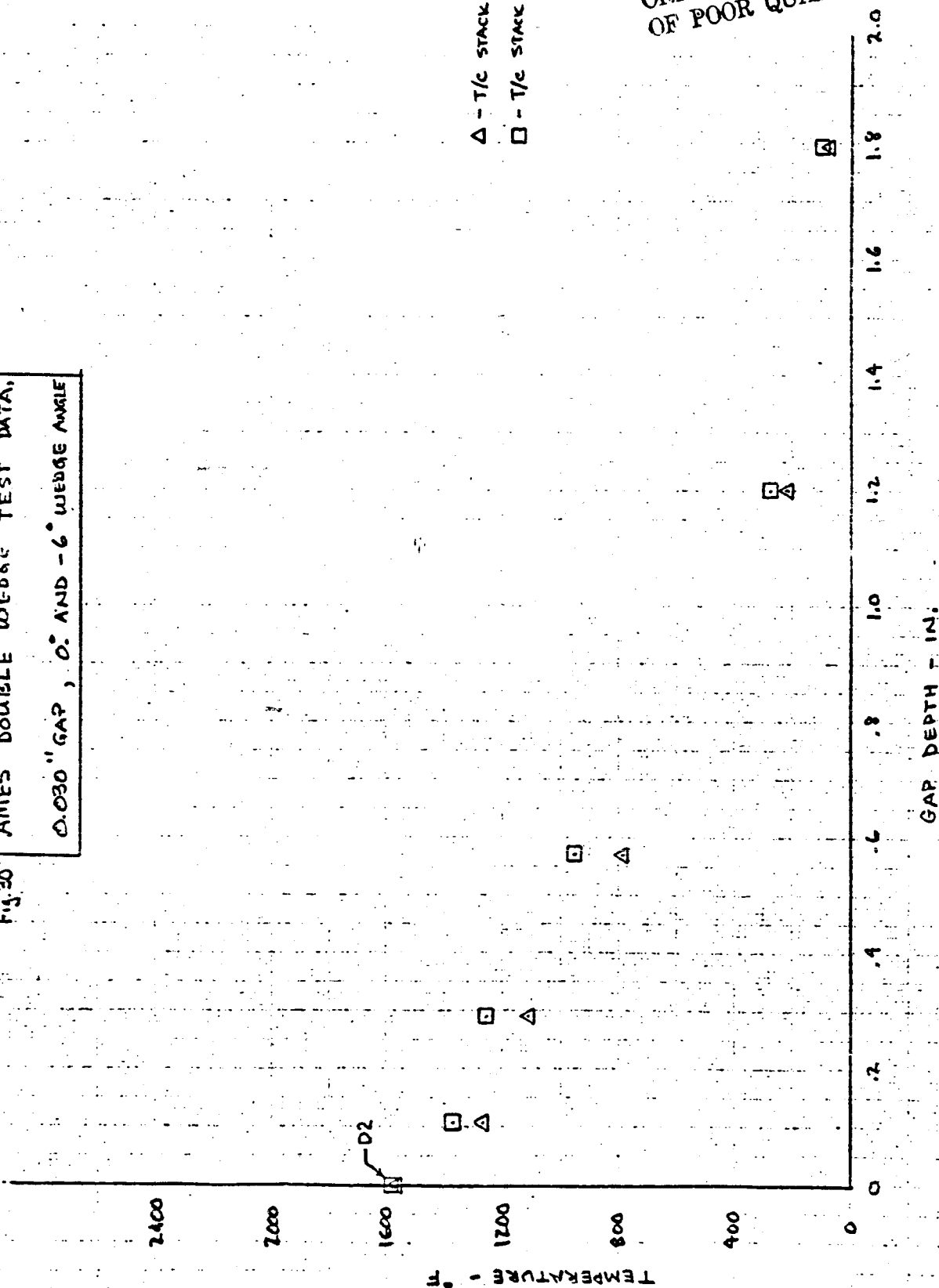
Fig. 29



△ - T/C STACK D3, RUN 28 (0°)
□ - T/C STACK D3, RUN 32 (-6°)

AMES DOUBLE WEDGE TEST DATA,
0.030" GAP, 0° AND -6° WEDGE ANGLE

Fig. 30

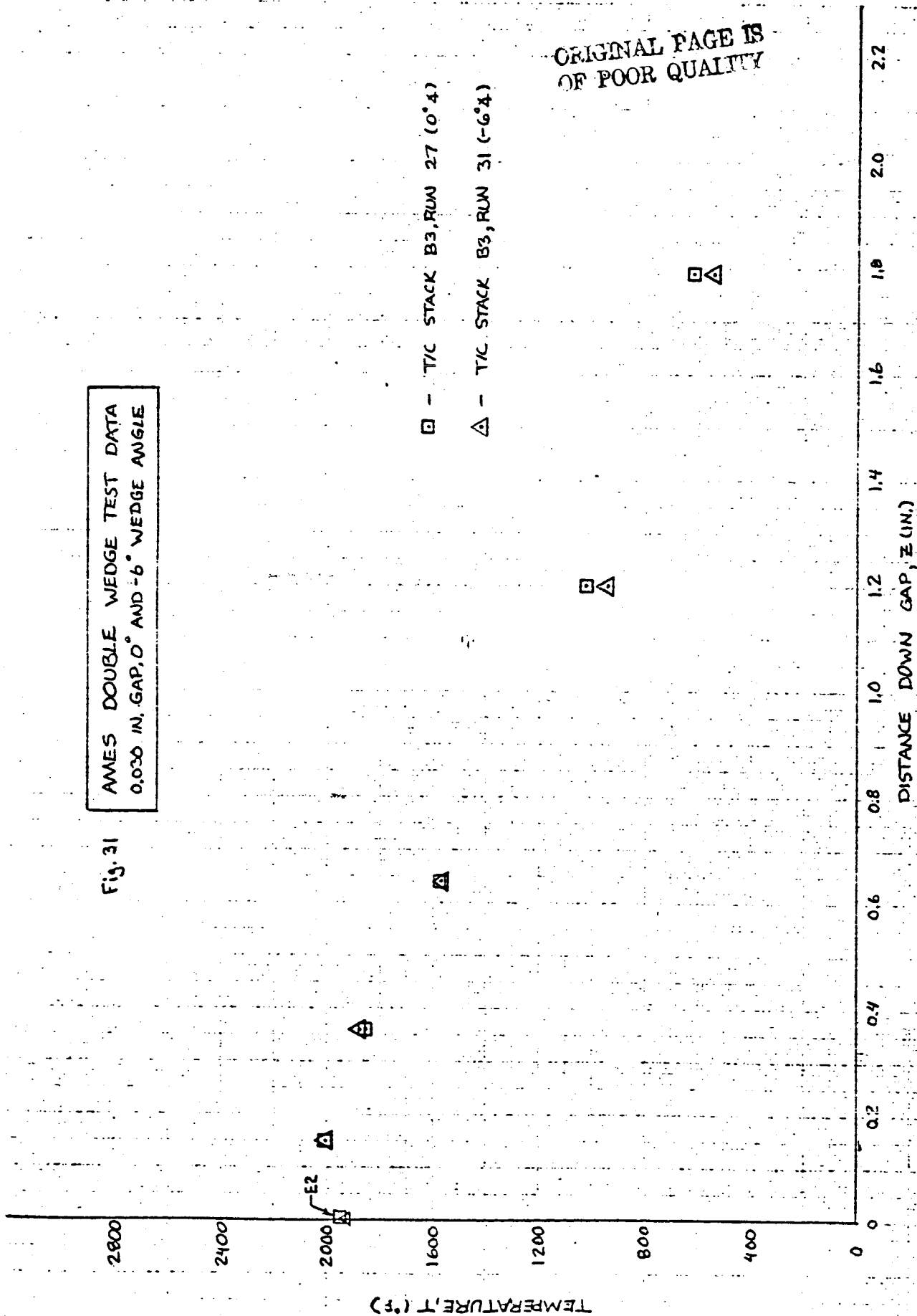


△ - T/C STACK #2, RUN 28(0°)
□ - T/C STACK #2, RUN 32(-6°)

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Fig. 31

AMES DOUBLE WEDGE TEST DATA
0.030 IN. GAP, 0° AND -6° WEDGE ANGLE



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AMES DOUBLE WEDGE TEST DATA
Q030 IN. GAP, 0° AND -6° WEDGE ANGLE

Fig. 32

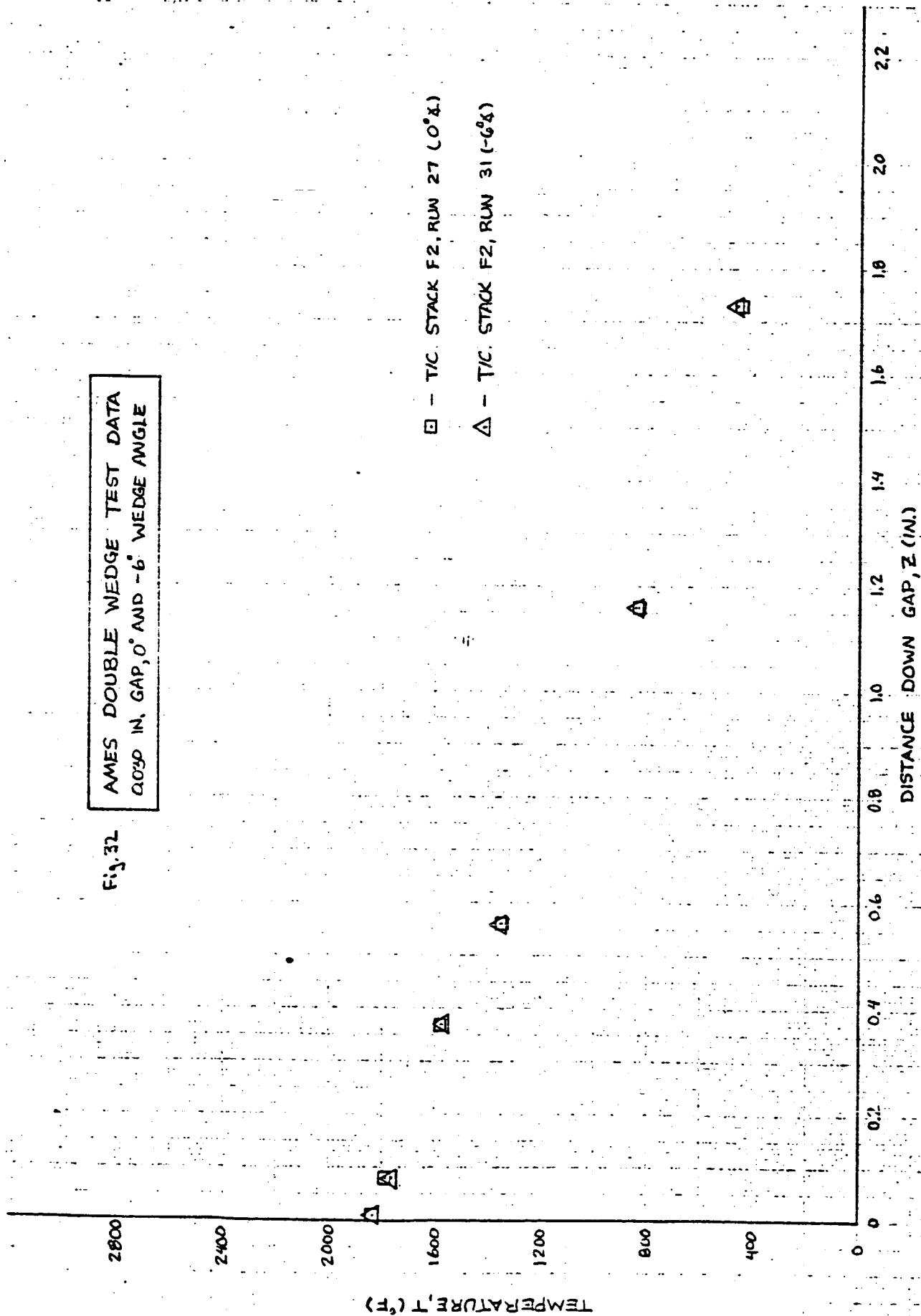


Fig. 33

AMES DOUBLE WEDGE TEST DATA
0.030 IN. GAP, 0° AND -6° WEDGE ANGLE

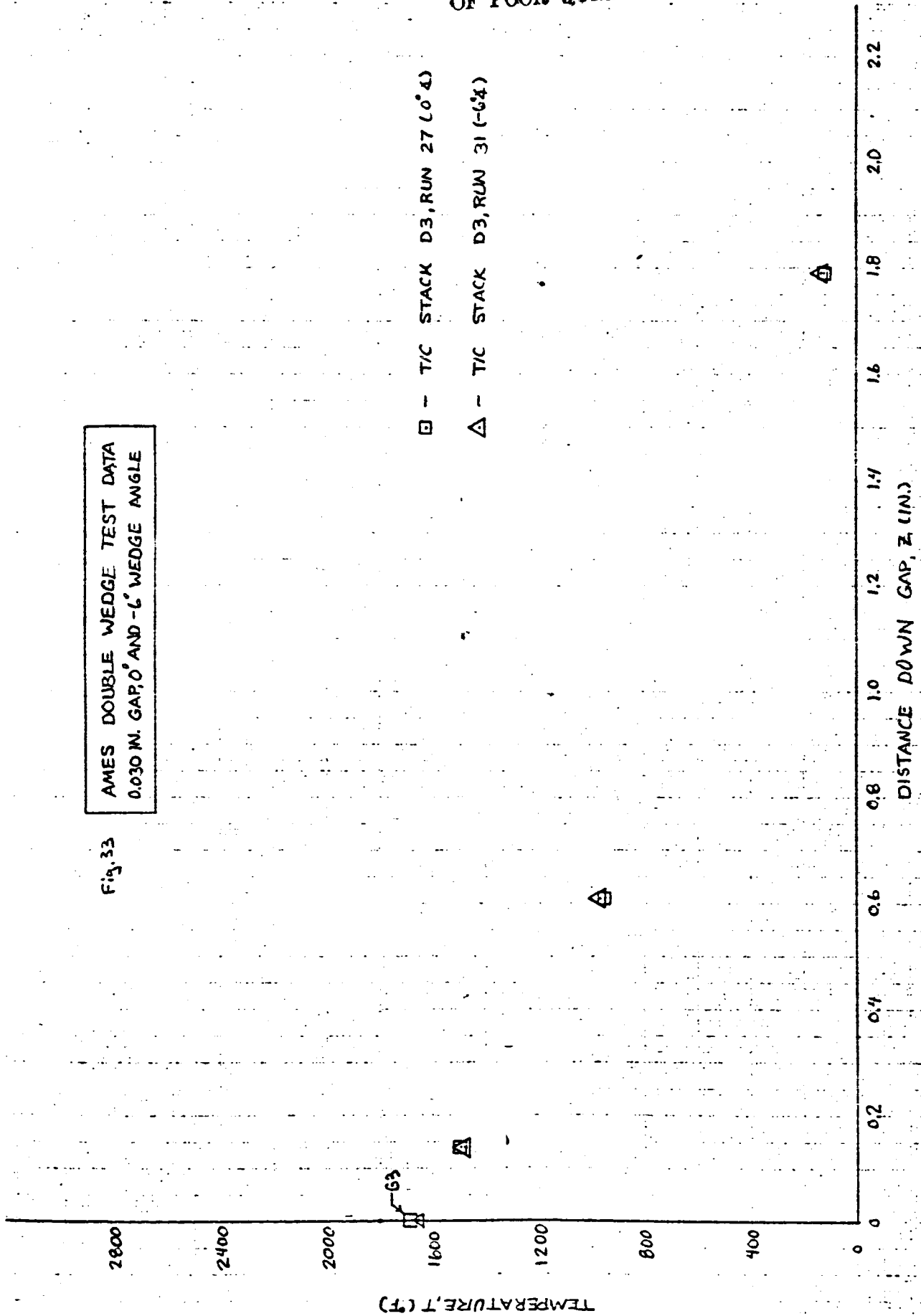


Fig. 34

AMES DOUBLE WEDGE TEST DATA
0.030 IN. GAP, 0° AND -6° WEDGE ANGLE

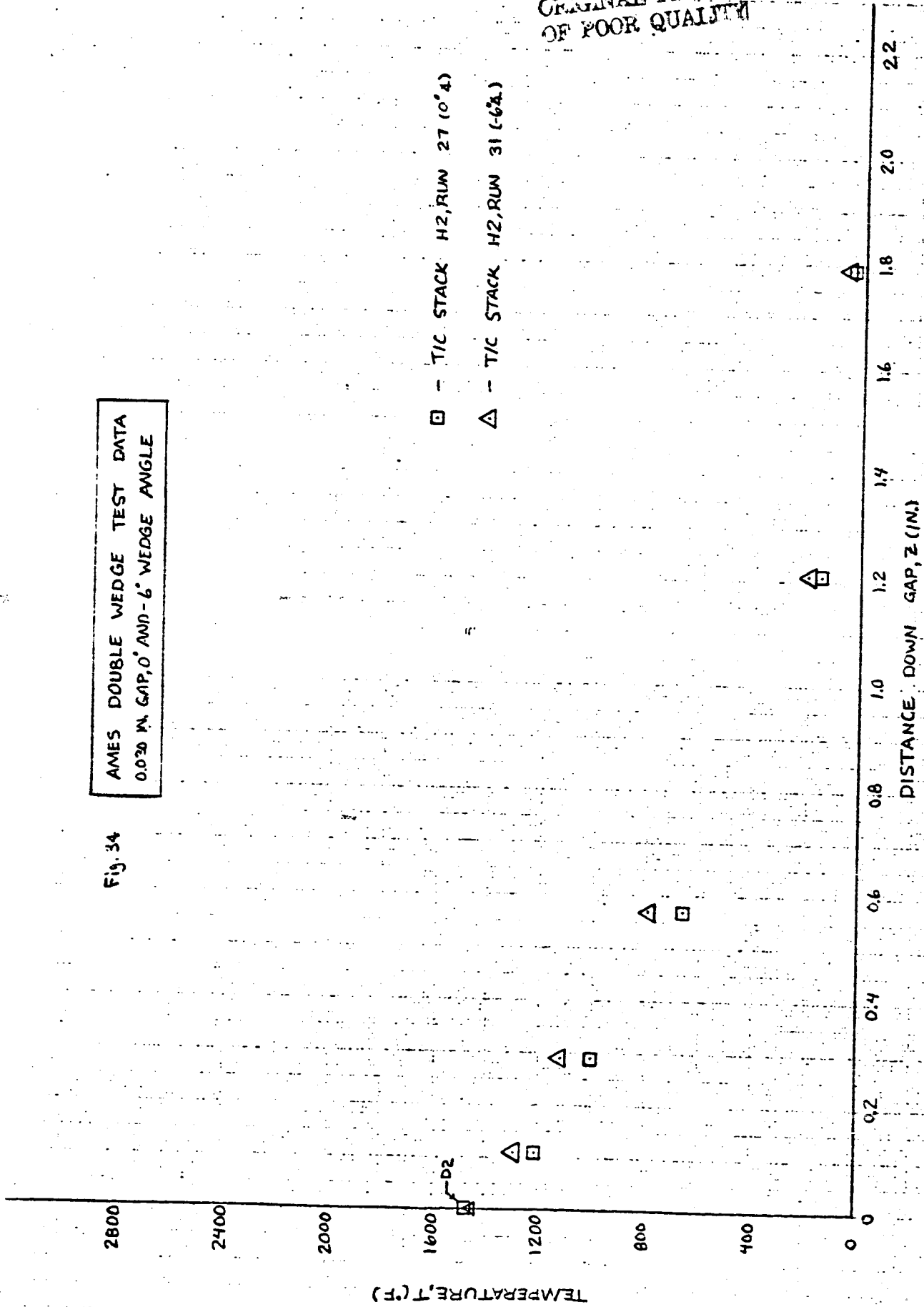
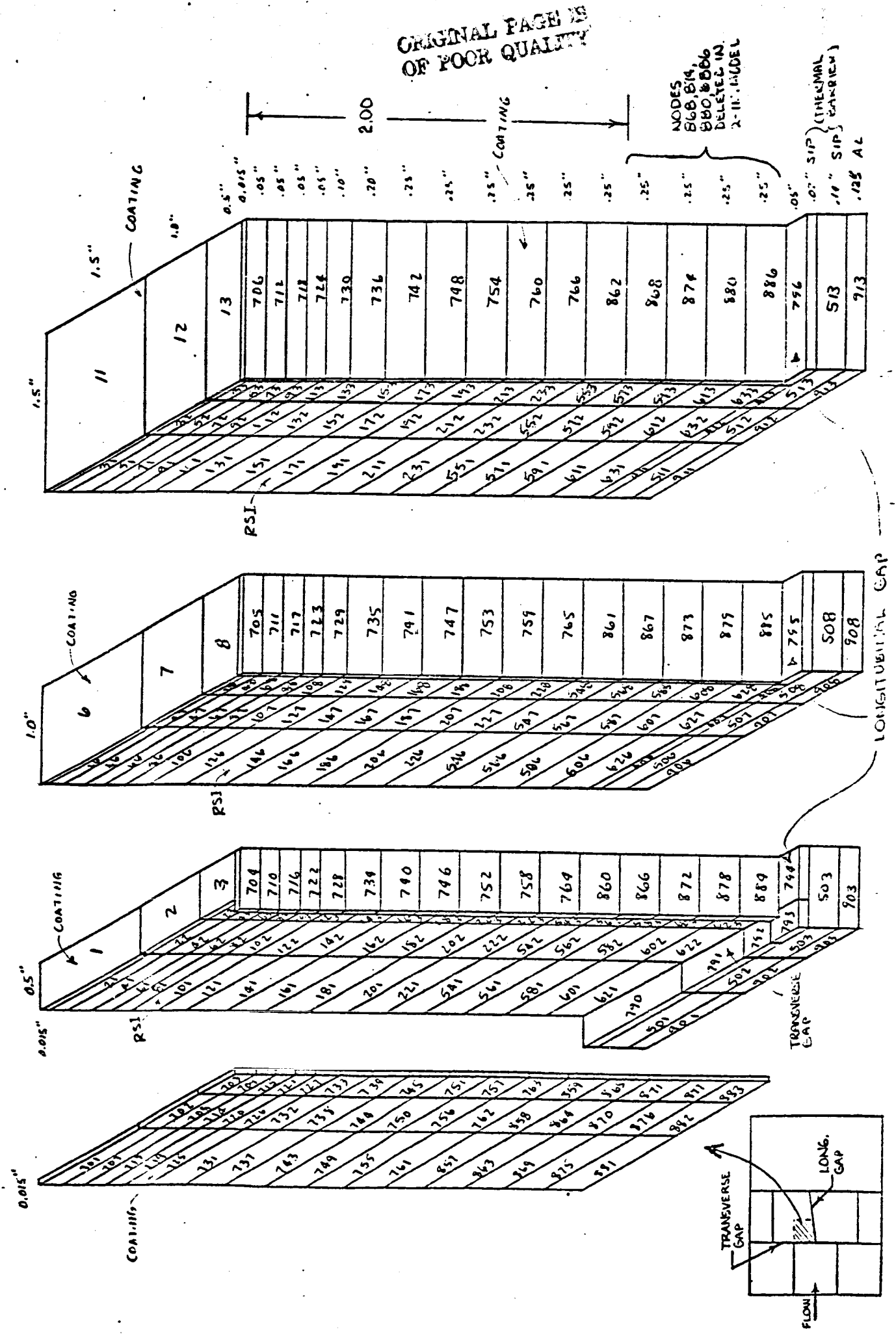
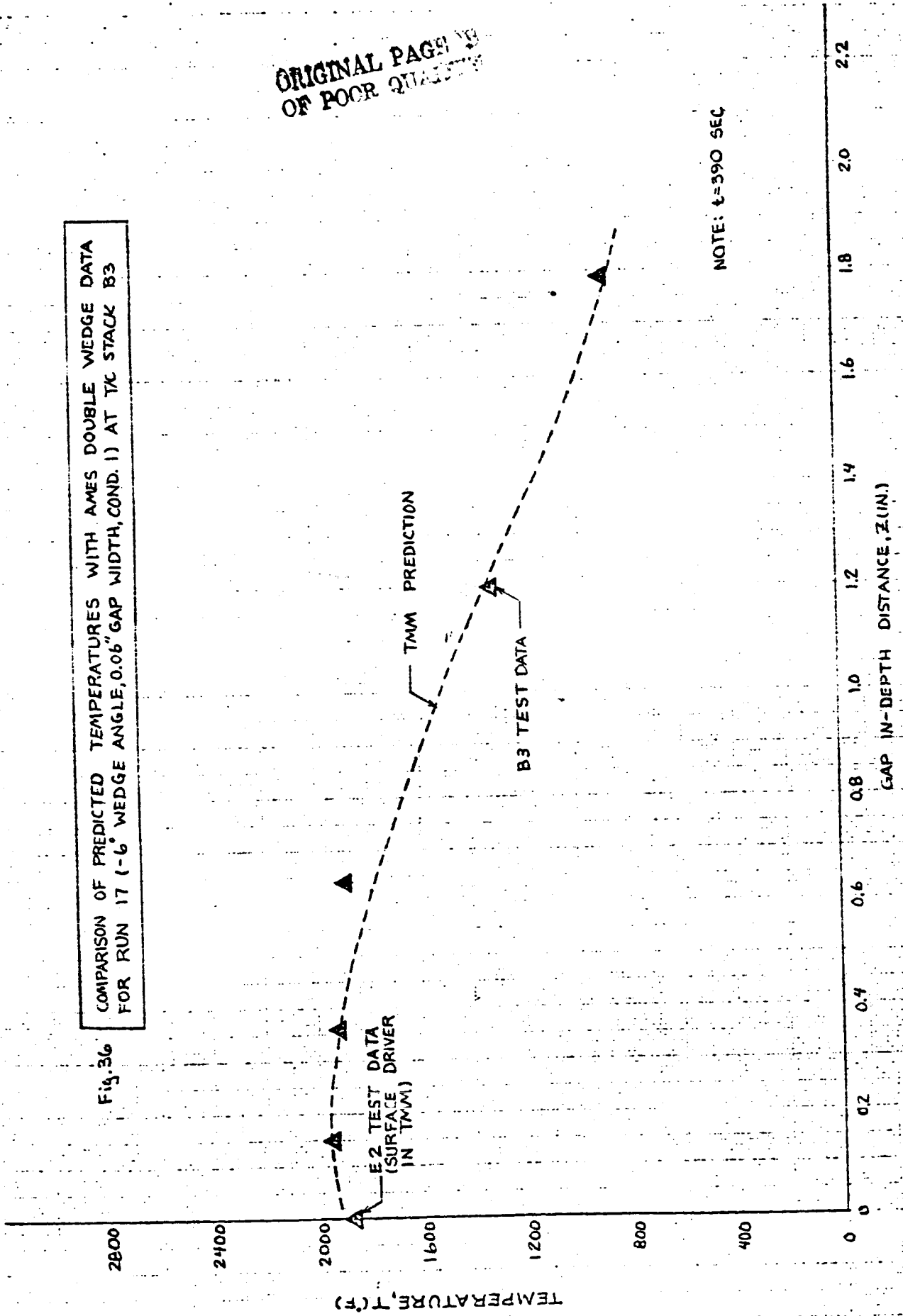


Fig. 35 '3-D TMM 1/4 TILE 3" thick



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Fig. 36
COMPARISON OF PREDICTED TEMPERATURES WITH AMES DOUBLE WEDGE DATA
FOR RUN 17 (-6° WEDGE ANGLE, 0.06" GAP WIDTH, COND. 1) AT TC STACK B3



NOTE: $t = 390$ SEC

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FIG. 37
COMPARISON OF PREDICTED TEMPERATURES WITH AMES DOUBLE WEDGE DATA
FOR RUN 20 (-6° WEDGE ANGLE, 0.06" GAP WIDTH, COND. 1-1/2) AT T/C STACK B3

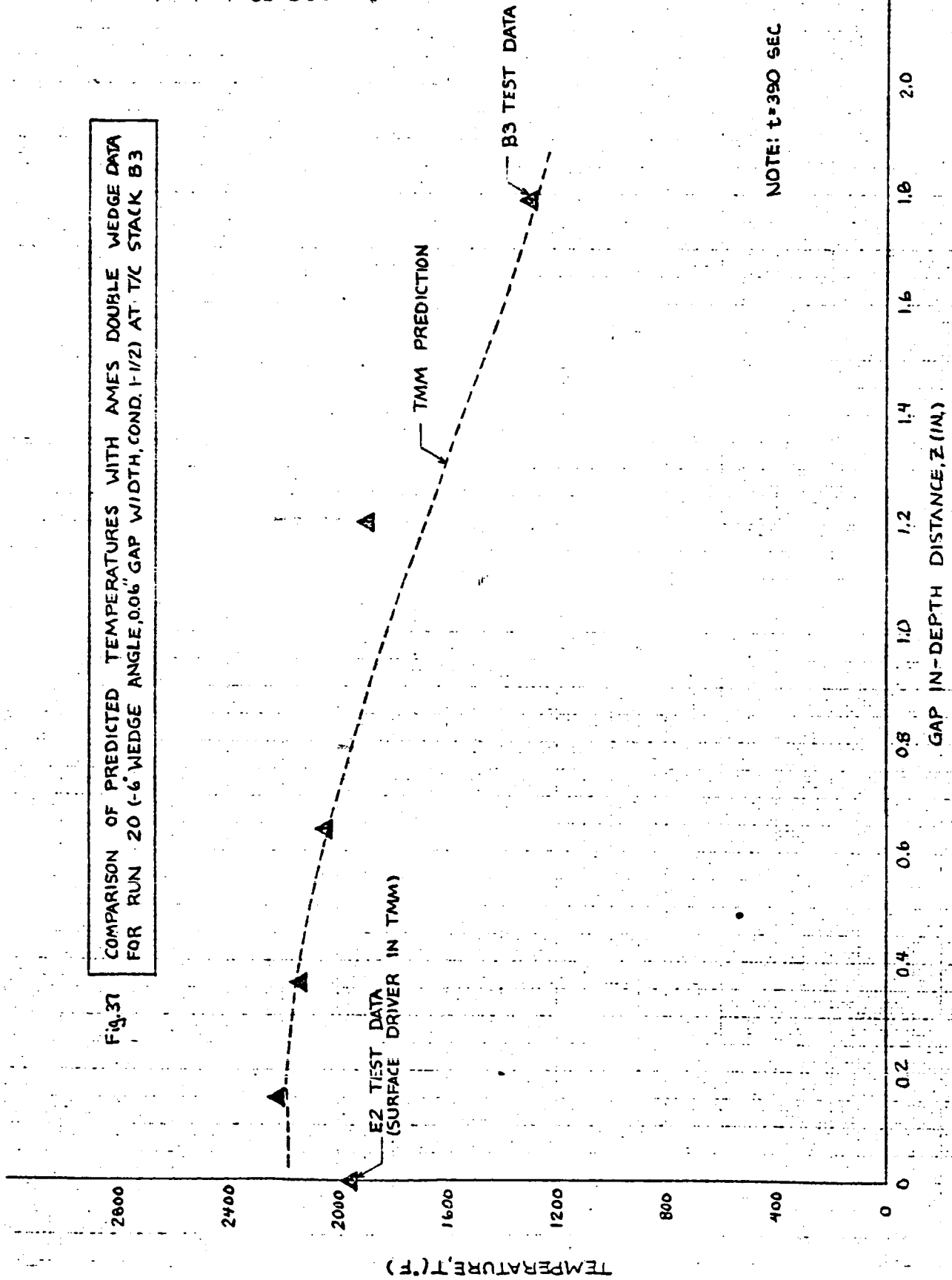
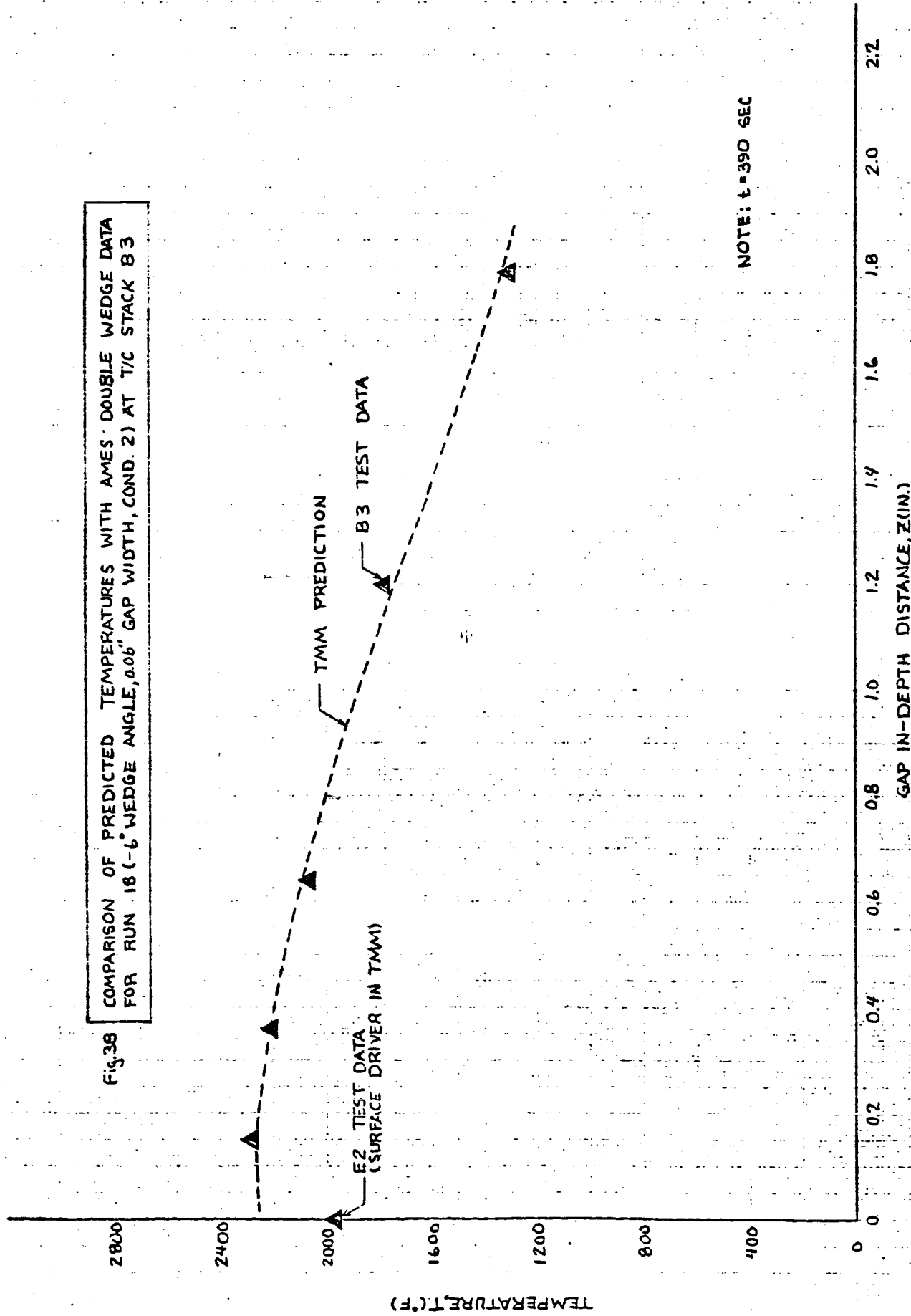


Fig. 38 COMPARISON OF PREDICTED TEMPERATURES WITH AMES DOUBLE WEDGE DATA FOR RUN 18 (-6° WEDGE ANGLE, 0.06" GAP WIDTH, COND. 2) AT T/C STACK B3



NOTE: t = 390 SEC

FIG. 39 COMPARISON OF PREDICTED TEMPERATURES WITH AMES DOUBLE WEDGE DATA FOR RUN 22 (0° WEDGE ANGLE, 0.06" GAP WIDTH, COND. 1) AT T/C STACK B3

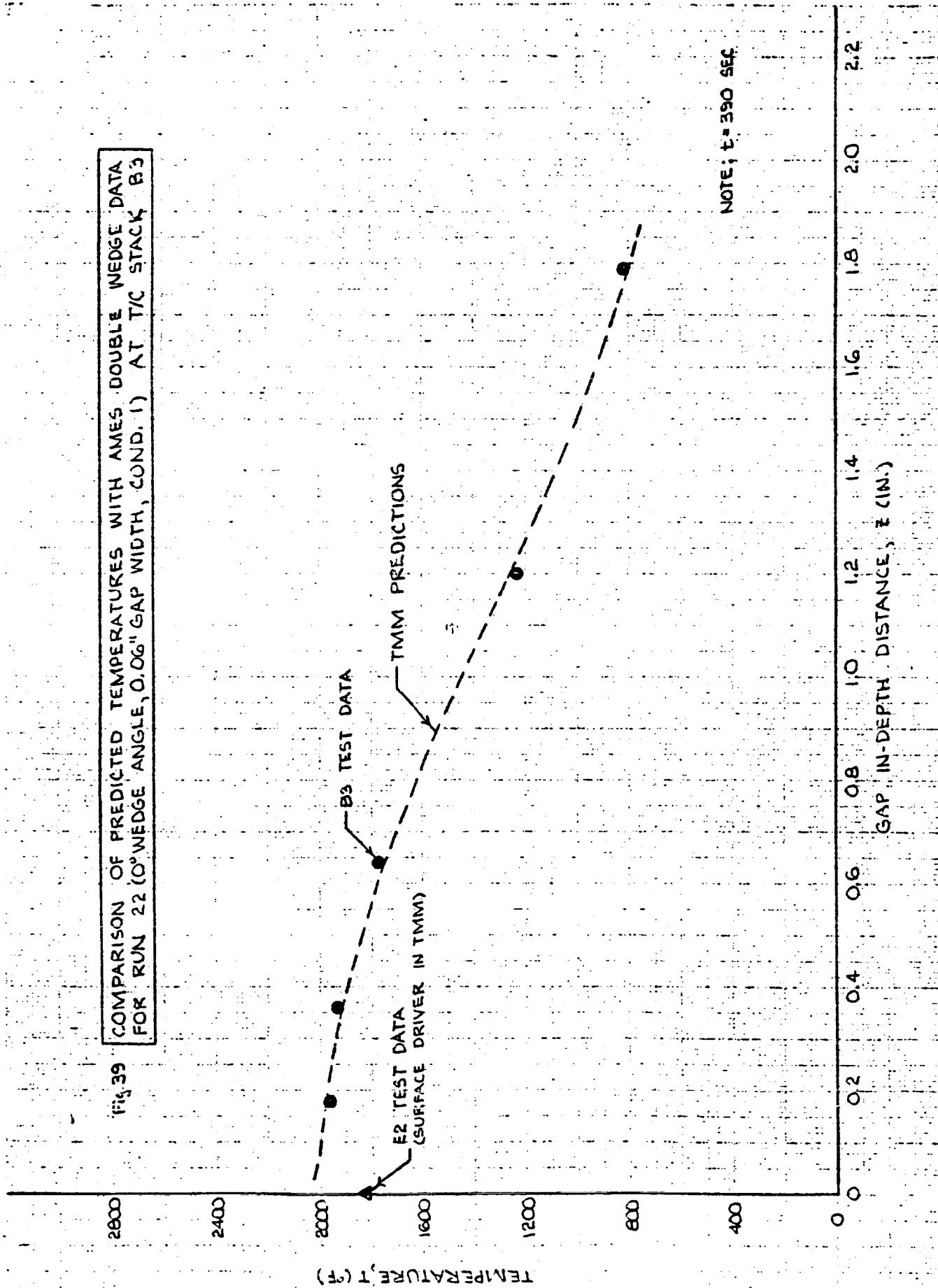
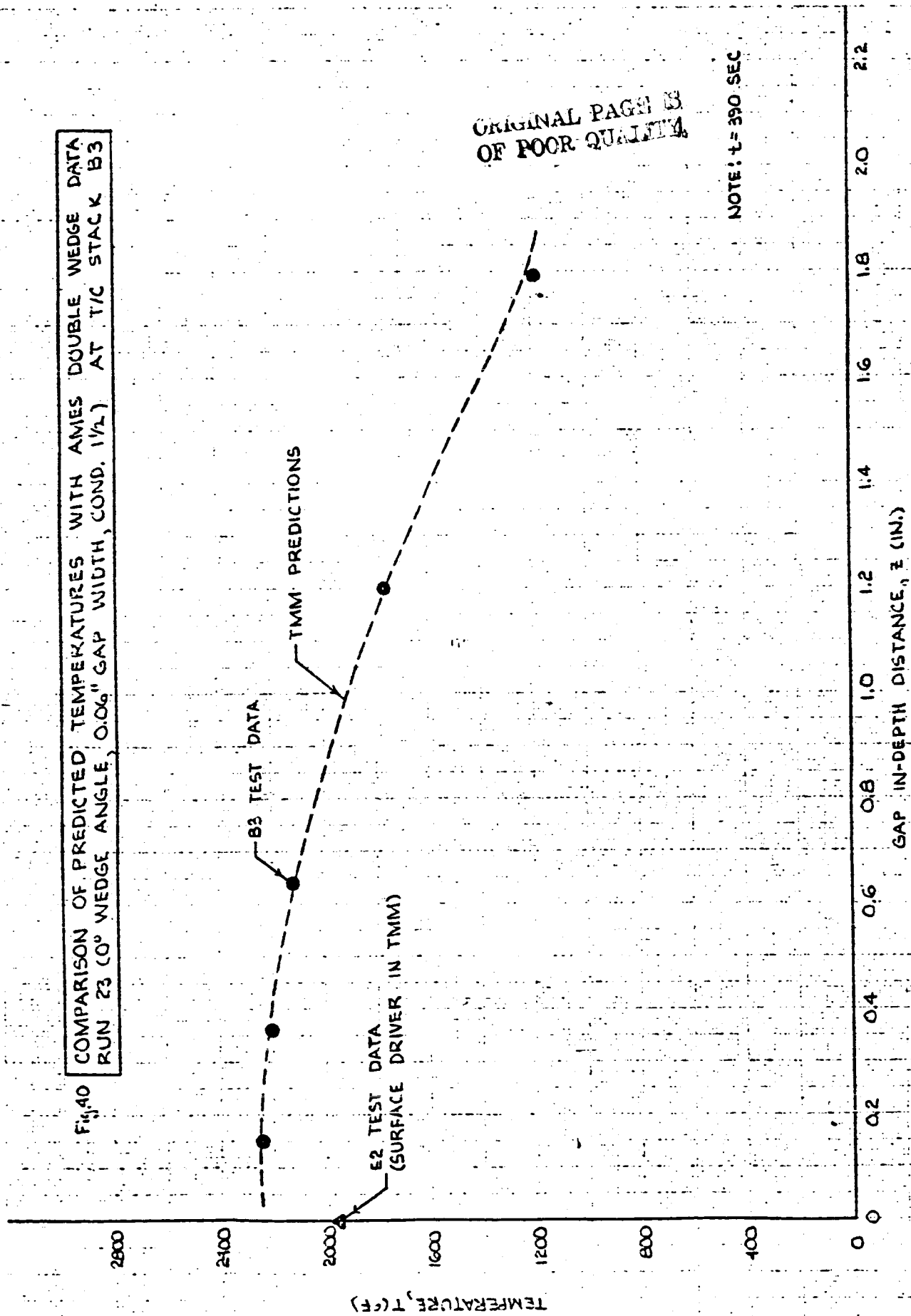


Fig. 40

COMPARISON OF PREDICTED TEMPERATURES WITH AMES DOUBLE WEDGE DATA
RUN 23 (0° WEDGE ANGLE, 0.06" GAP WIDTH, COND. 1½) AT T/C STACK B3



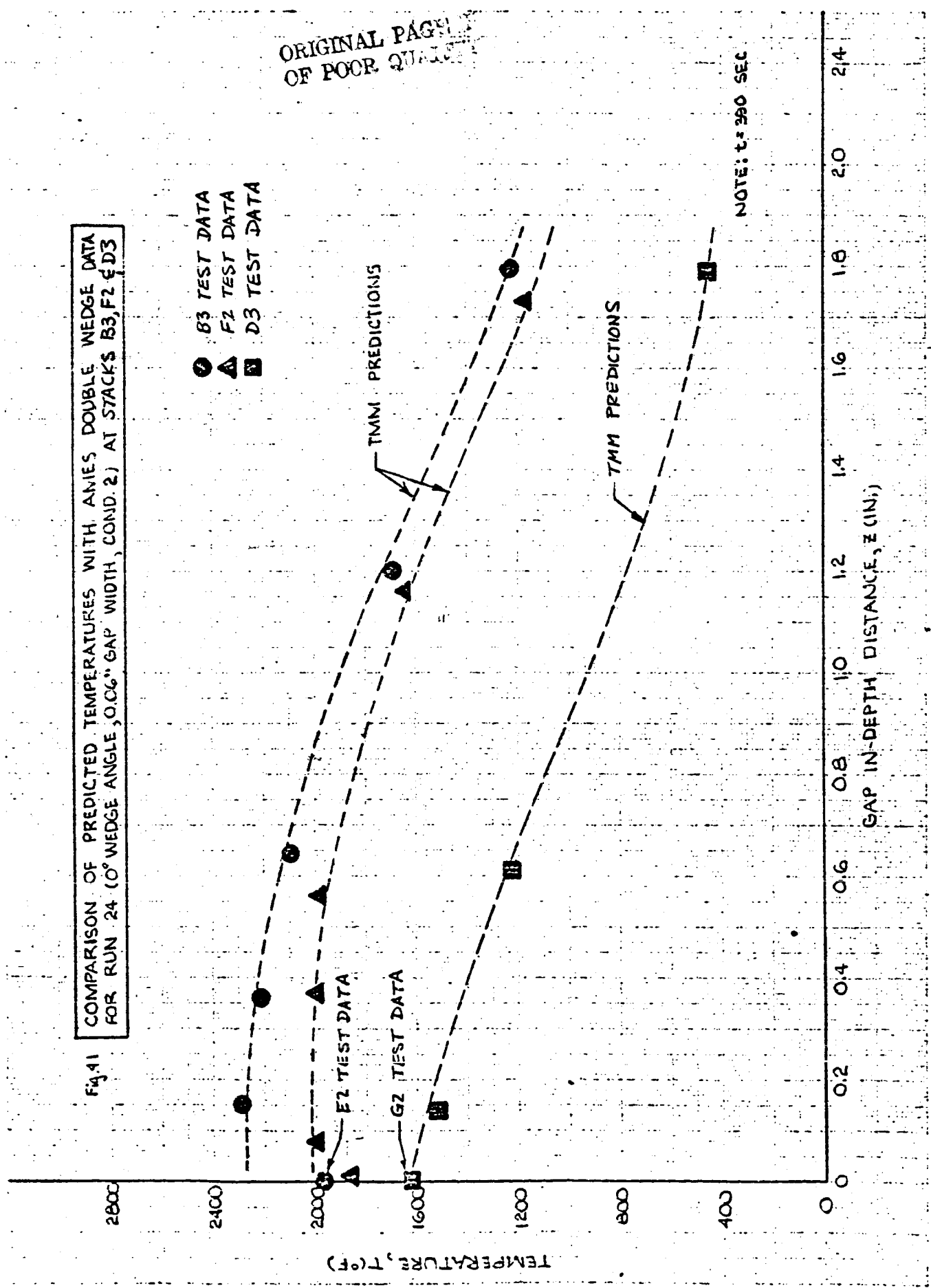
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NOTE: t = 390 SEC

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Fig. 41 COMPARISON OF PREDICTED TEMPERATURES WITH AMIES DOUBLE WEDGE DATA FOR RUN 24 (0° WEDGE ANGLE, 0.06" GAP WIDTH, COND. 2) AT STACKS B3, F2 & D3

- B3 TEST DATA
- ▲ F2 TEST DATA
- D3 TEST DATA



COMPARISON OF PREDICTED TEMPERATURES WITH AMES DOUBLE WEDGE DATA
FOR RUN 25 (0° WEDGE ANGLE, 0.03" GAP WIDTH, COND. 1) AT STACK B3

Fig. 42

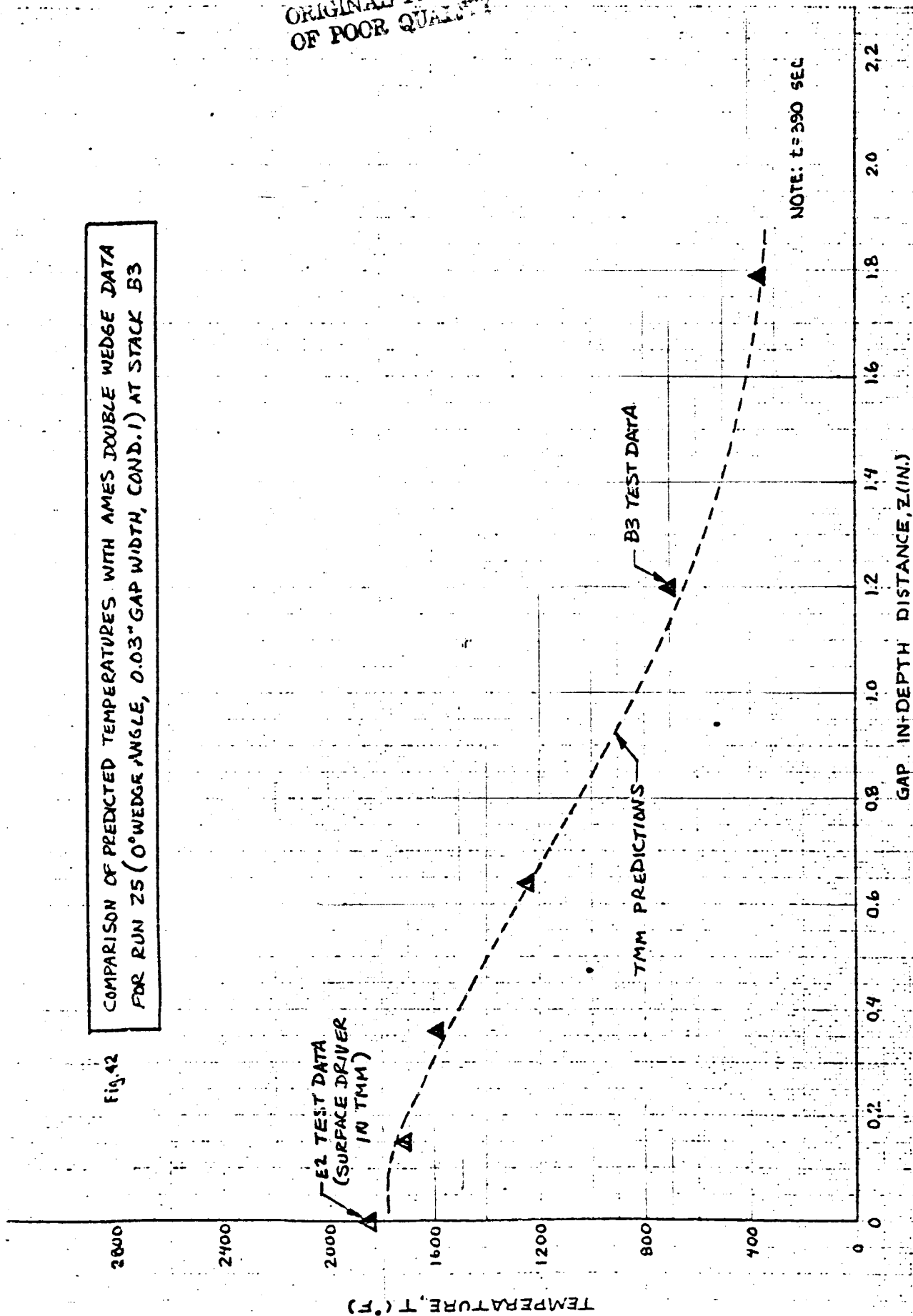
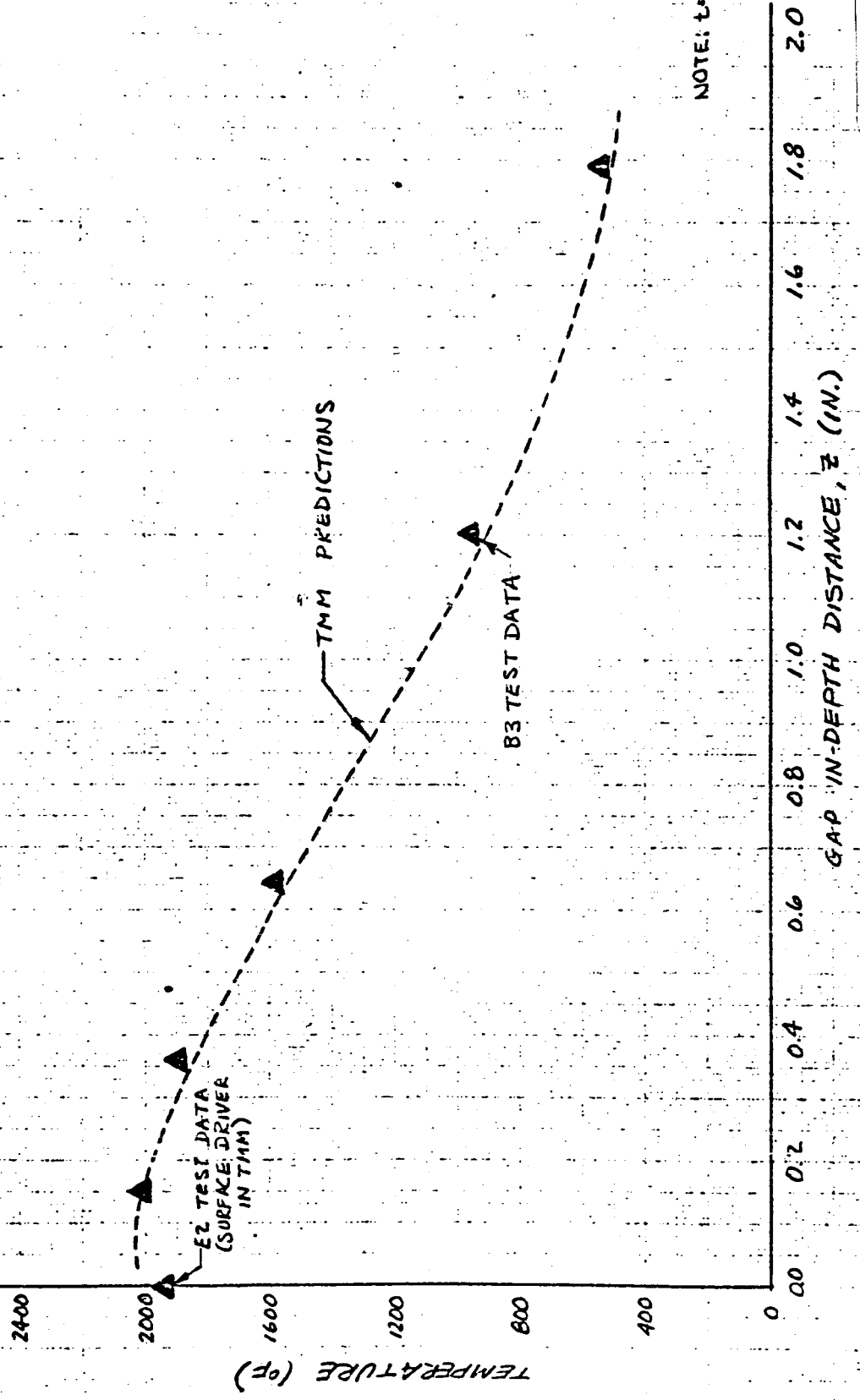


FIG. 13
 COMPARISON OF PREDICTED TEMPERATURES WITH AMES DOUBLE WEDGE DATA
 FOR RUN 26 (0° WEDGE ANGLE, 0.03" GAP WIDTH, COND. 1 1/2) AT STACK B3



NOTE: $t = 390$ SEC

FIG. 44 COMPARISON OF PREDICTED TEMPERATURES WITH AMES DOUBLE WEDGE DATA FOR RUN 27 (0° WEDGE ANGLE, 0.03" GAP WIDTH, COND. 2) AT T/C STACKS B3 & F2.

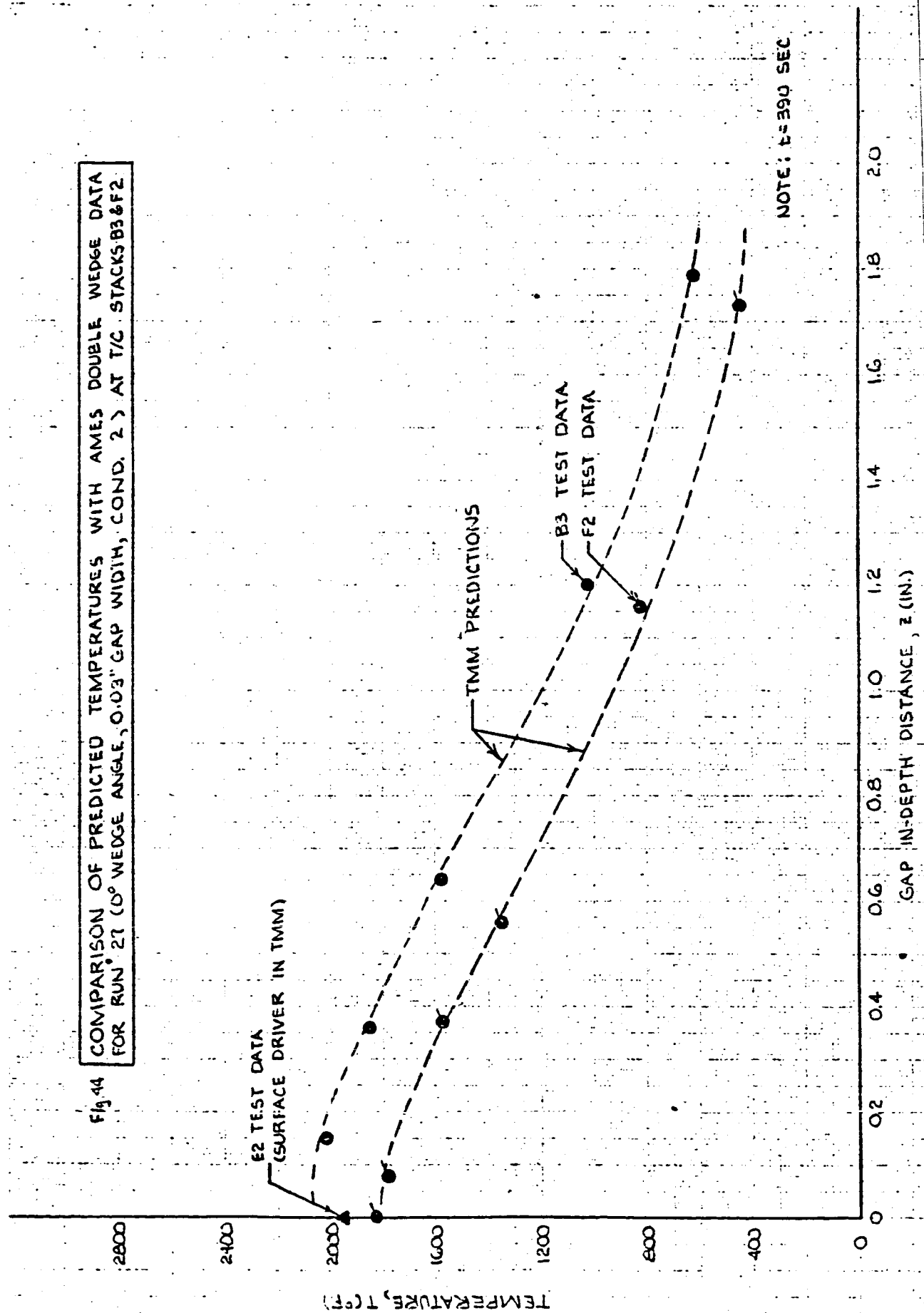
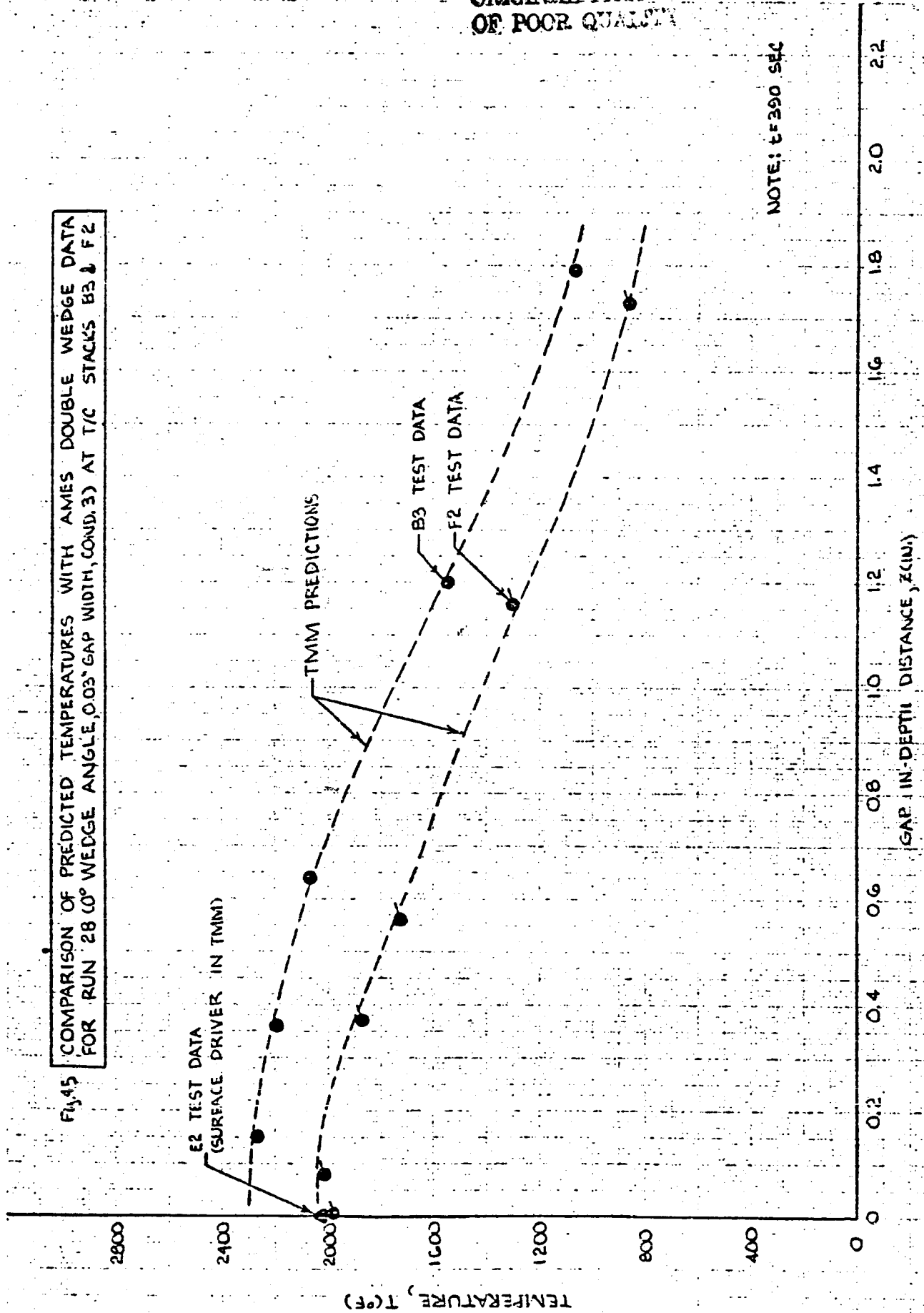
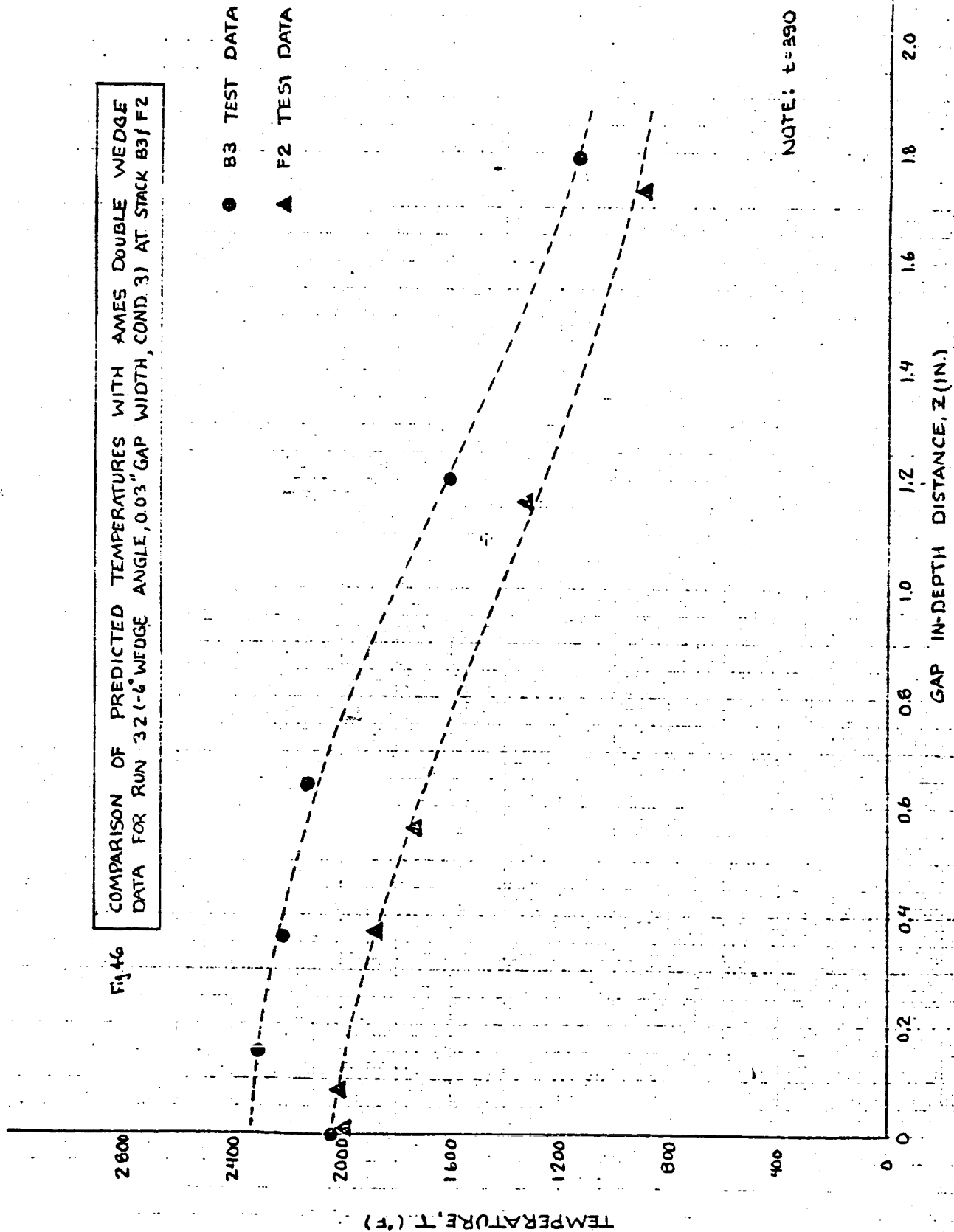


FIG. 45 COMPARISON OF PREDICTED TEMPERATURES WITH AMES DOUBLE WEDGE DATA
FOR RUN 28 (0° WEDGE ANGLE, 0.03" GAP WIDTH, COND. 3) AT T/C STACKS B3 & F2



NOTE: t=390 SEC

Fig 46 COMPARISON OF PREDICTED TEMPERATURES WITH AMES DOUBLE WEDGE
DATA FOR RUN 32 (6° WEDGE ANGLE, 0.03" GAP WIDTH, COND. 3) AT STACK B3/F2



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Fig. 47 COMPARISON OF PREDICTED TEMPERATURES WITH AMES DOUBLE WEDGE DATA AT LOCATION H2 FOR RUNS 25 AND 29

▲ RUN 29 (COND. 1, 0.03" G.W., -6" W.A.)
 △ RUN 25 (COND. 1, 0.03" G.W., 0" W.A.)

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NOTE: t = 390 SEC

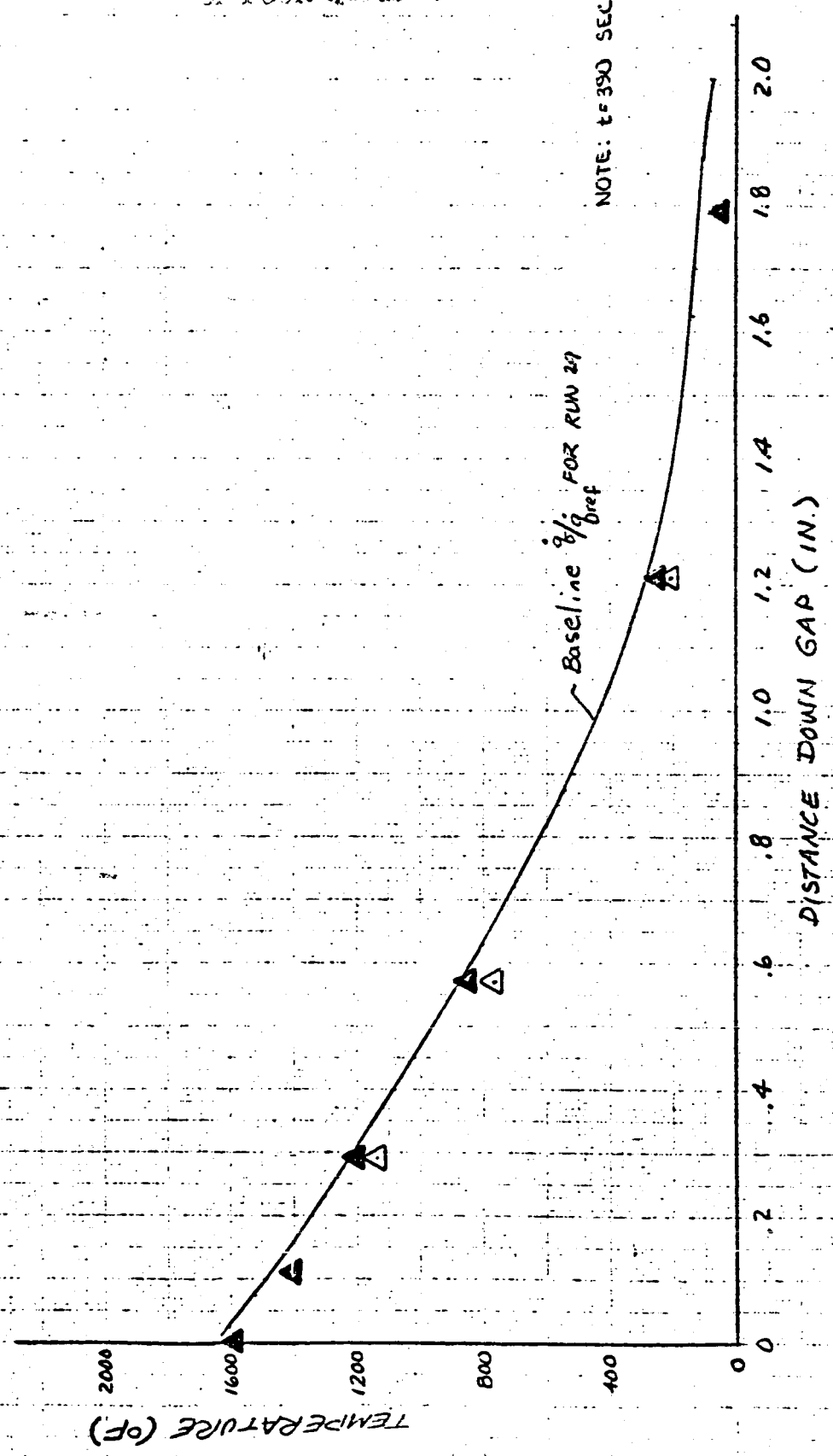


Fig. 18

COMPARISON OF PREDICTED TEMPERATURES WITH AMES DOUBLE WEDGE DATA AT LOCATION H2 FOR RUNS 26 AND 30

- ▲ RUN 30 (COND. $1\frac{1}{2}$, 0.03°G.W. , 5.6°W.A.)
- △ RUN 26 (COND. $1\frac{1}{2}$, 0.03°G.W. , 0°W.A.)

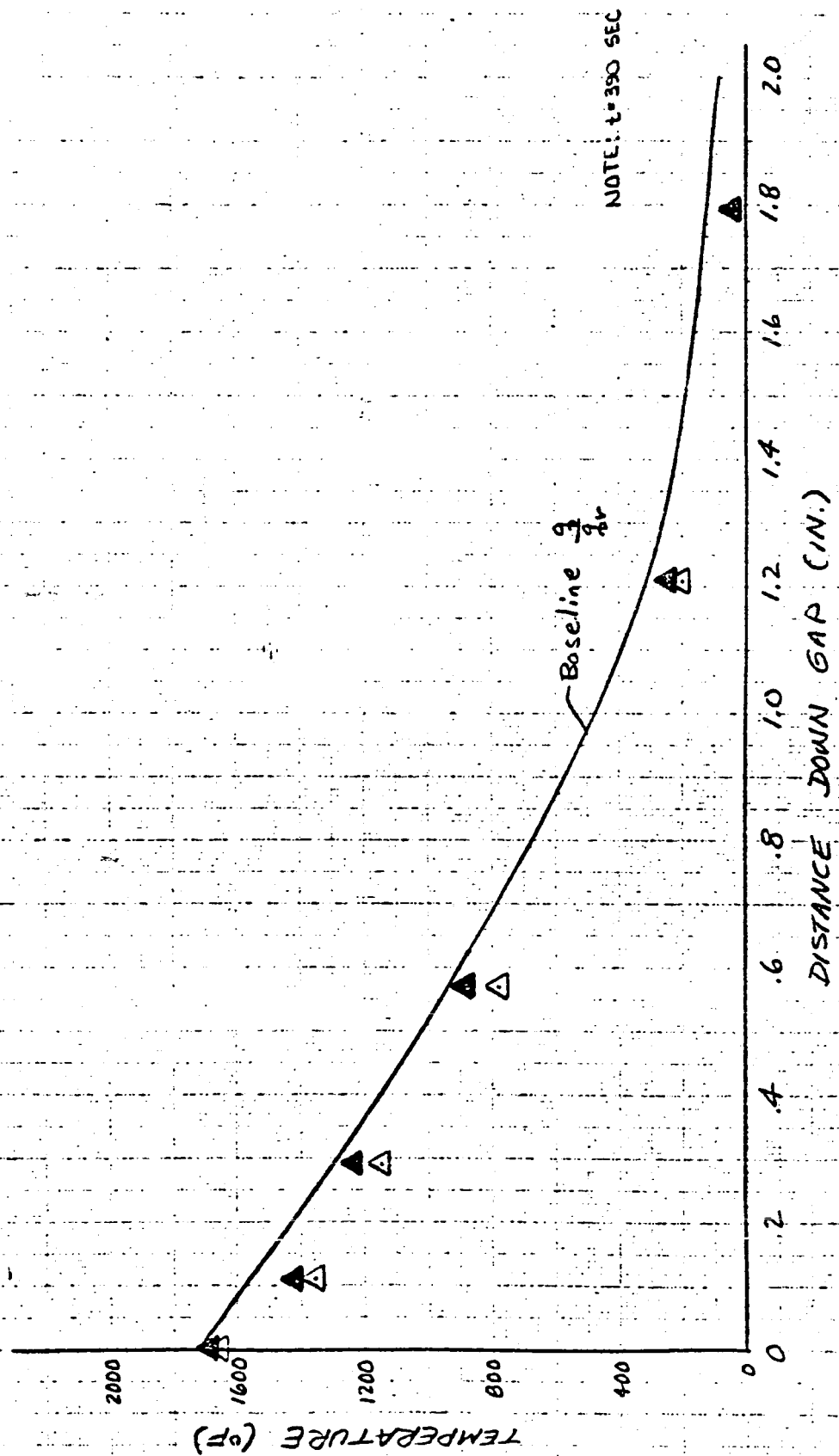


Fig. 49

COMPARISON OF PREDICTED TEMPERATURES WITH AMES DOUBLE WEDGE DATA AT LOCATION H2 FOR RUNS 27 AND 31

- ▲ RUN 31 (COND. 2, 0.03" G.W., -6° W.A.)
- △ RUN 27 (COND. 2, 0.03" G.W., 0° W.A.)

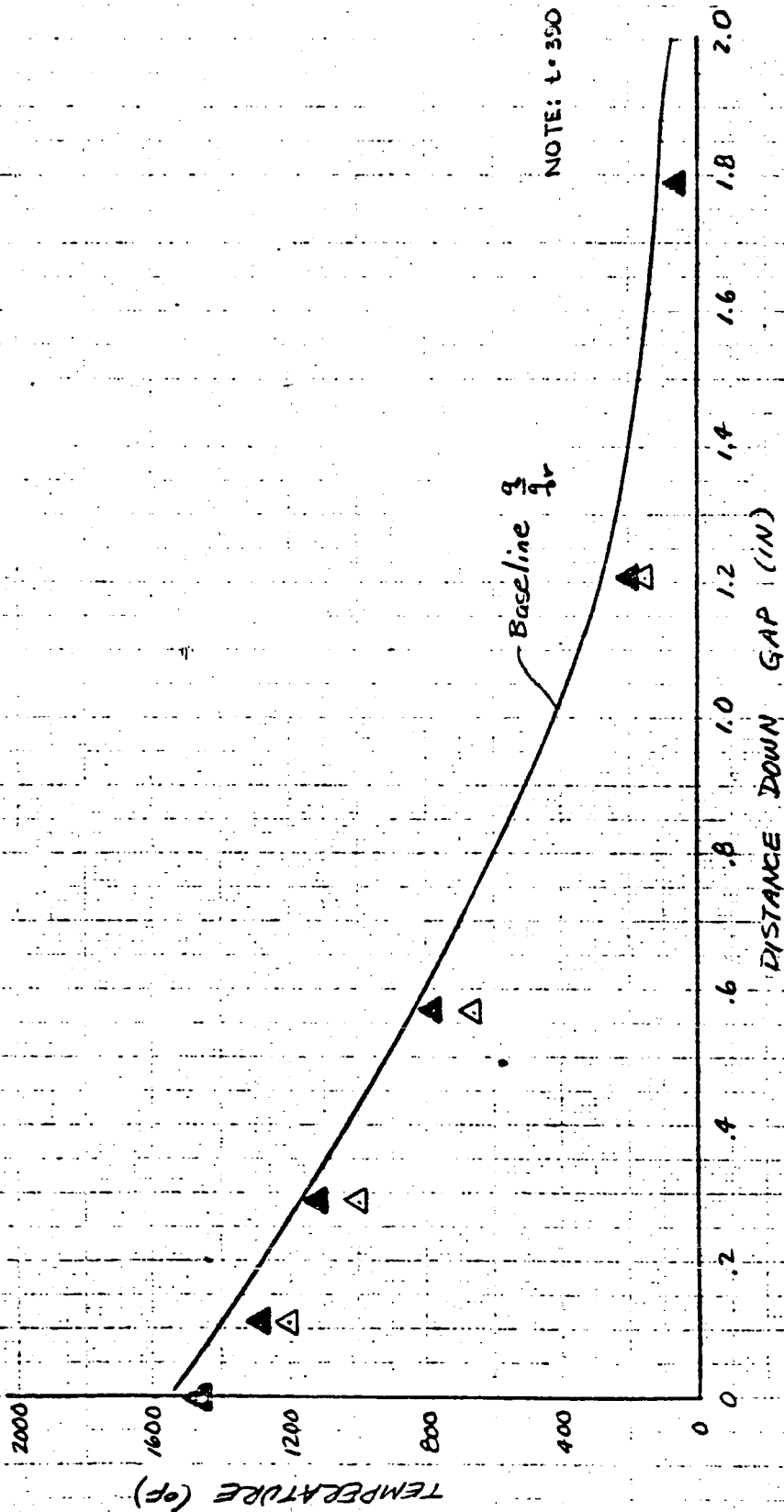


FIG. 50
COMPARISON OF PREDICTED TEMPERATURES WITH AMES DOUBLE
WEDGE DATA AT LOCATION H2 FOR RUNS 28 AND 32

- ▲ RUN 32 (COND. 3, 0.03' G.W., -6° W.A.)
- △ RUN 28 (COND. 3, 0.03' G.W., 0° W.A.)

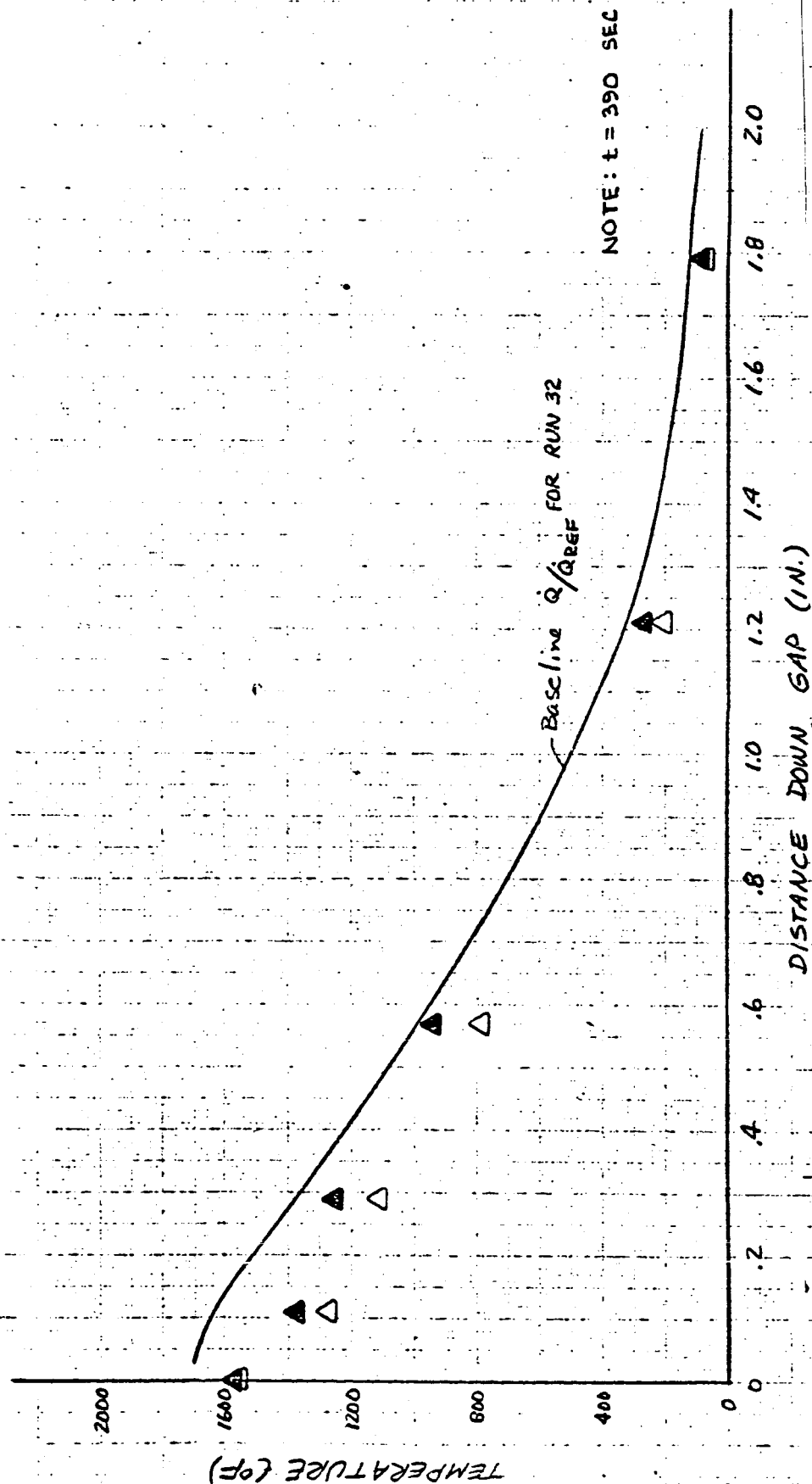


Fig. 51
 GAP IN-DEPTH TEMPERATURES AS A FUNCTION OF TIME
 FOR RUN 18 (6° WEDGE ANGLE, 0.06" GAP WIDTH, COND. 2)
 AT T/C STACK B3

T/C GAP DEPTH
 36 .15 IN.
 37 .36 IN.
 38 .64 IN.
 39 1.20 IN.
 40 1.79 IN.

○ □ △ ▽ ◇

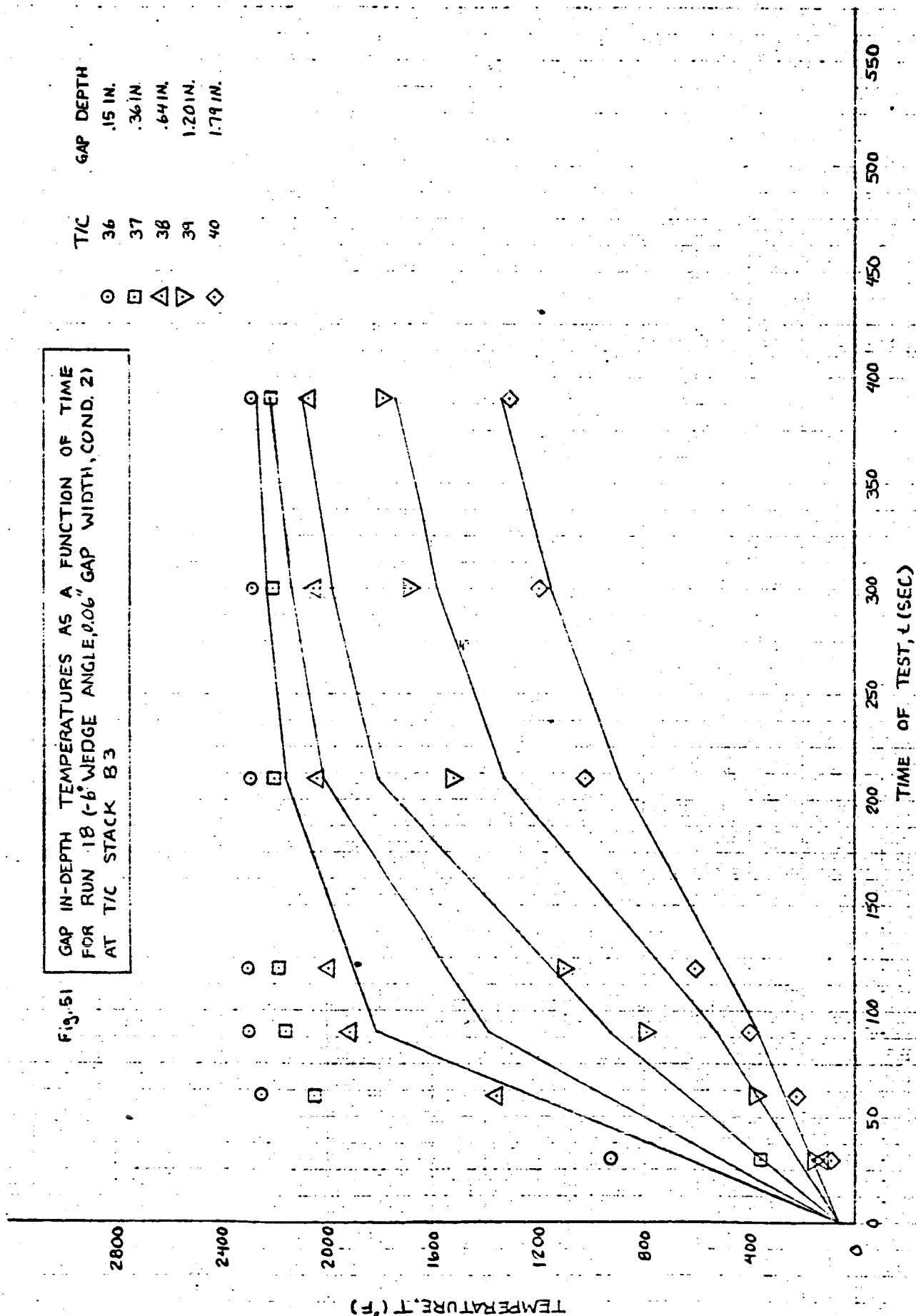
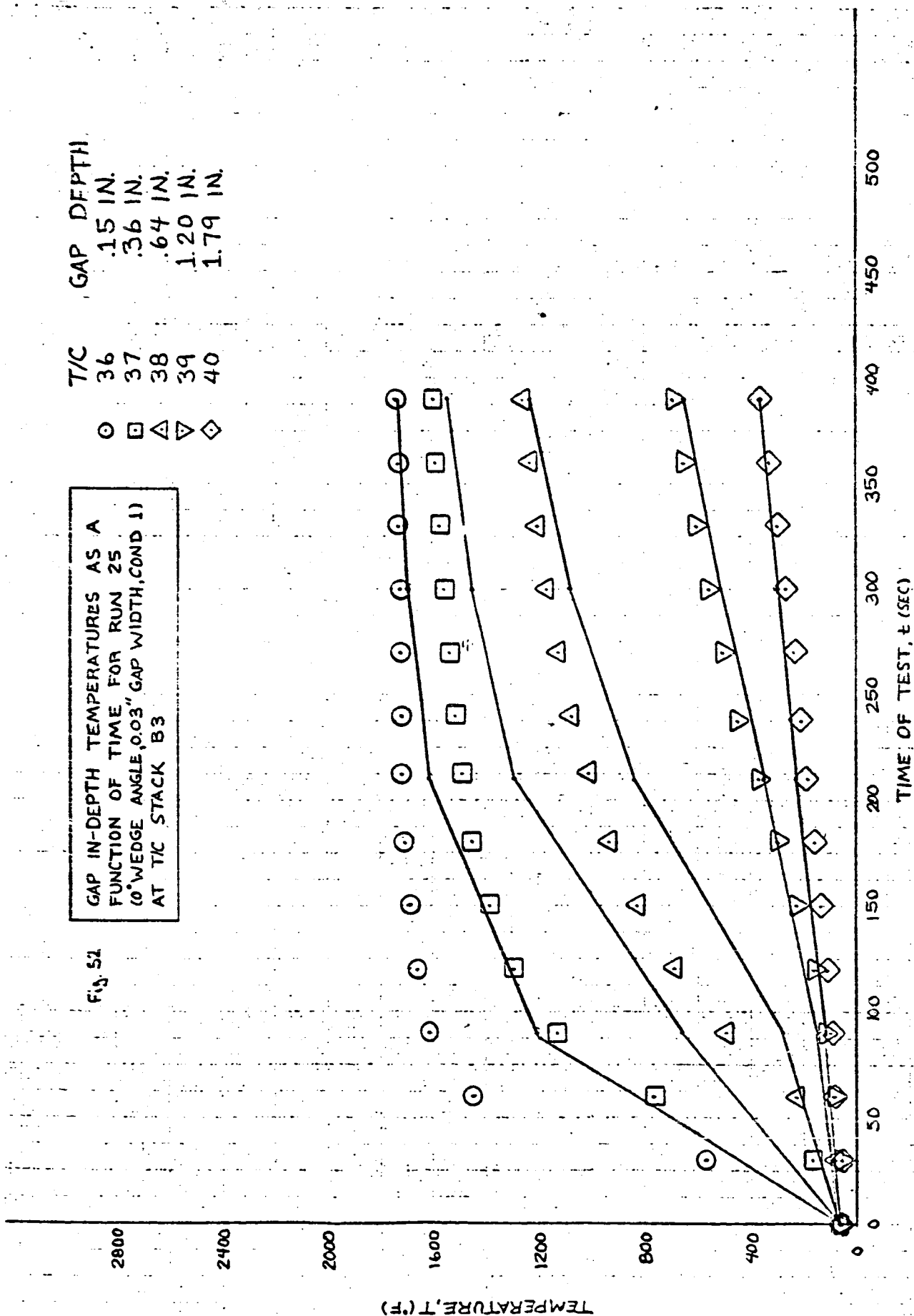


Fig. 51

GAP IN-DEPTH TEMPERATURES AS A
FUNCTION OF TIME FOR RUN 25
(0° WEDGE ANGLE, 0.03" GAP WIDTH, COND 1)
AT T/C STACK B3

T/C GAP DEPTH
36 .15 IN.
37 .36 IN.
38 .64 IN.
39 1.20 IN.
40 1.79 IN.

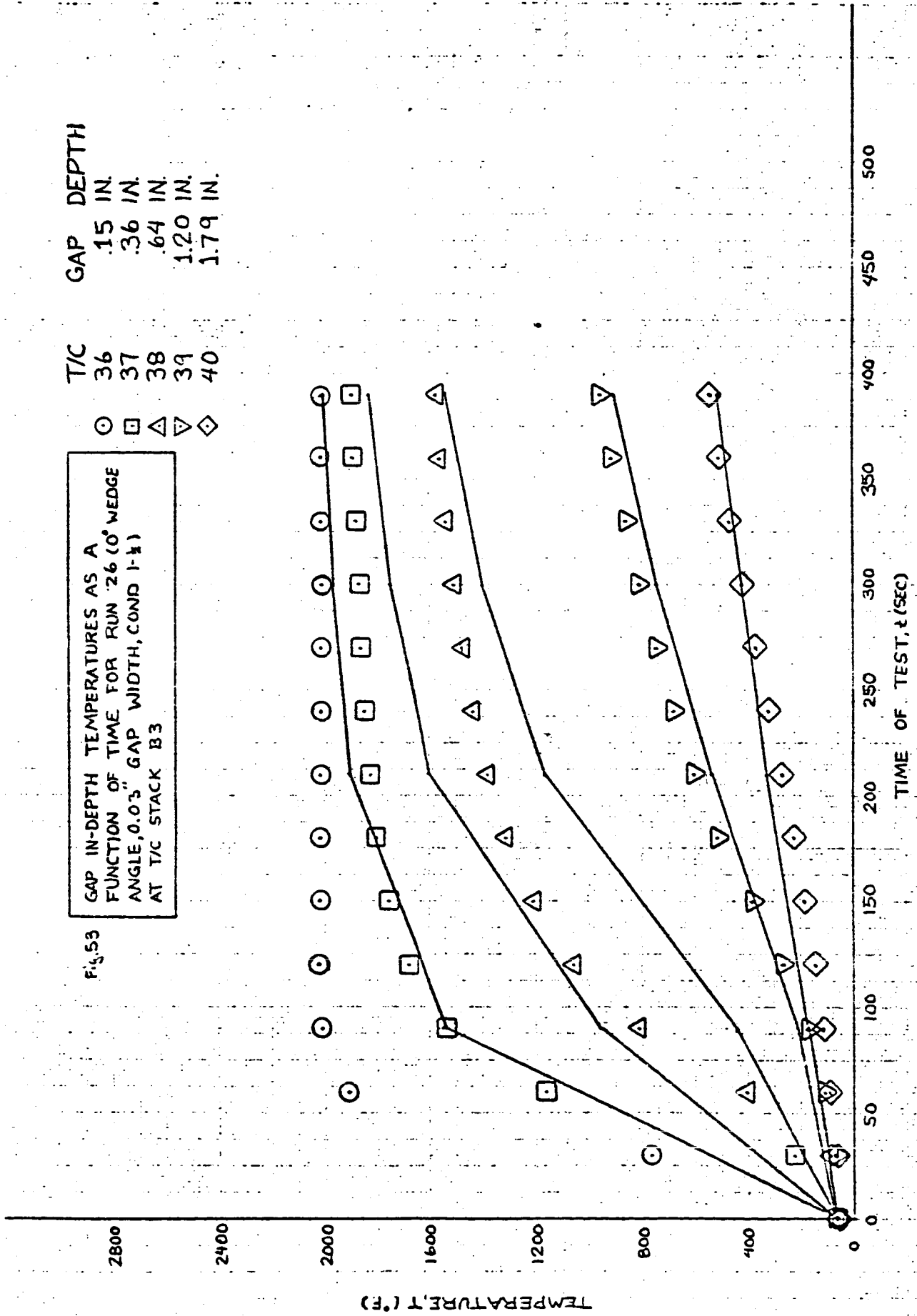


GAP DEPTH
 .15 IN.
 .36 IN.
 .64 IN.
 1.20 IN.
 1.79 IN.

T/C
 36
 37
 38
 39
 40

GAP IN-DEPTH TEMPERATURES AS A
 FUNCTION OF TIME FOR RUN 26 (0° WEDGE
 ANGLE, 0.03" GAP WIDTH, COND 1-1/2)
 AT T/C STACK B3

F4.53



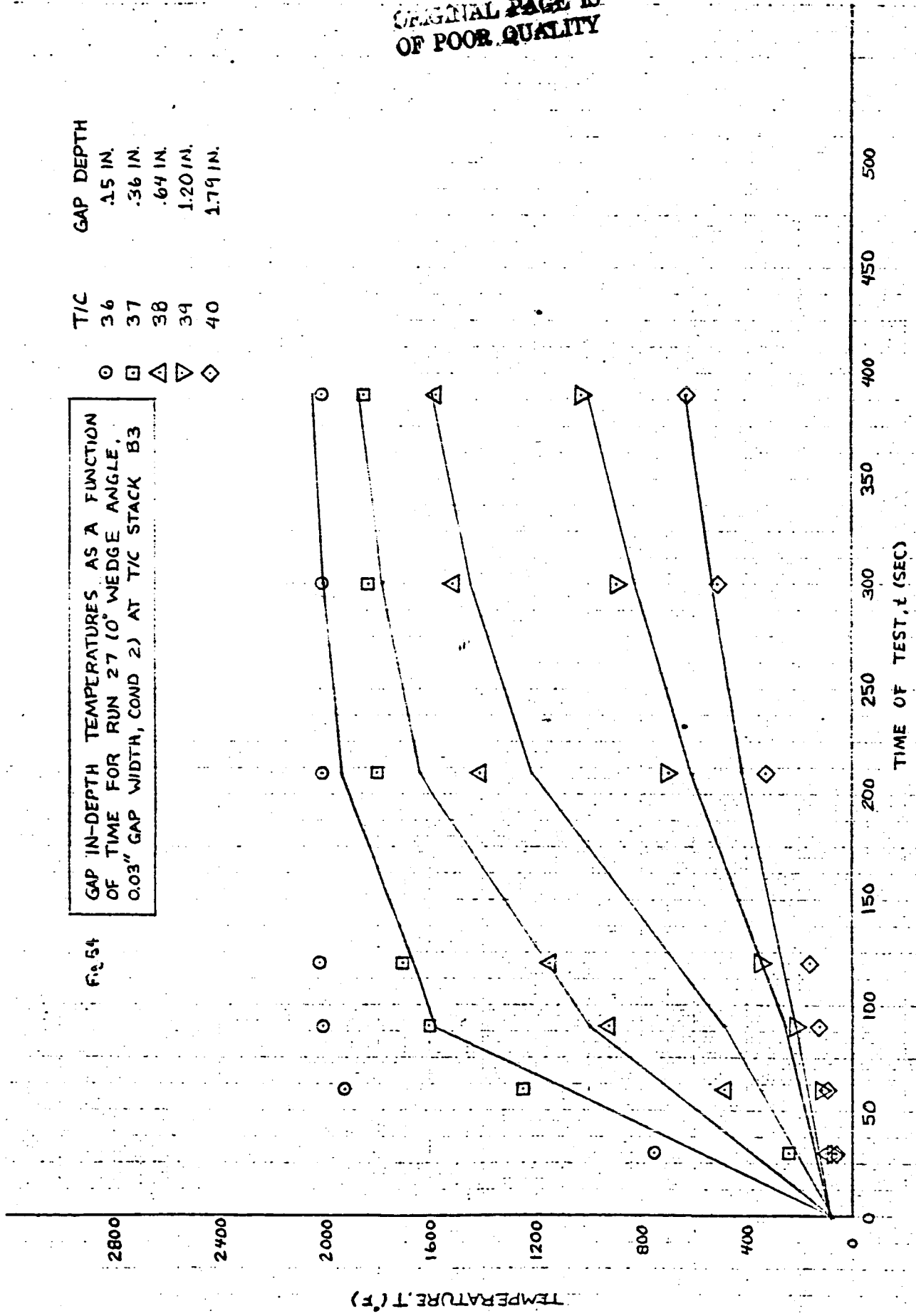
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T/C
36
37
38
39
40

GAP DEPTH
.15 IN.
.36 IN.
.64 IN.
1.20 IN.
1.79 IN.

GAP IN-DEPTH TEMPERATURES AS A FUNCTION
OF TIME FOR RUN 27 (0° WEDGE ANGLE,
0.03" GAP WIDTH, COND 2) AT T/C STACK B3

Fig. 54



T/C GAP DEPTH
 36 .15 IN.
 37 .36 IN.
 38 .64 IN.
 39 1.20 IN.
 40 1.79 IN.

Fig. 55 GAP IN-DEPTH TEMPERATURES AS A FUNCTION OF TIME FOR RUN 28 (0° WEDGE ANGLE, 0.03" GAP WIDTH, COND 3) AT T/C STACK B3

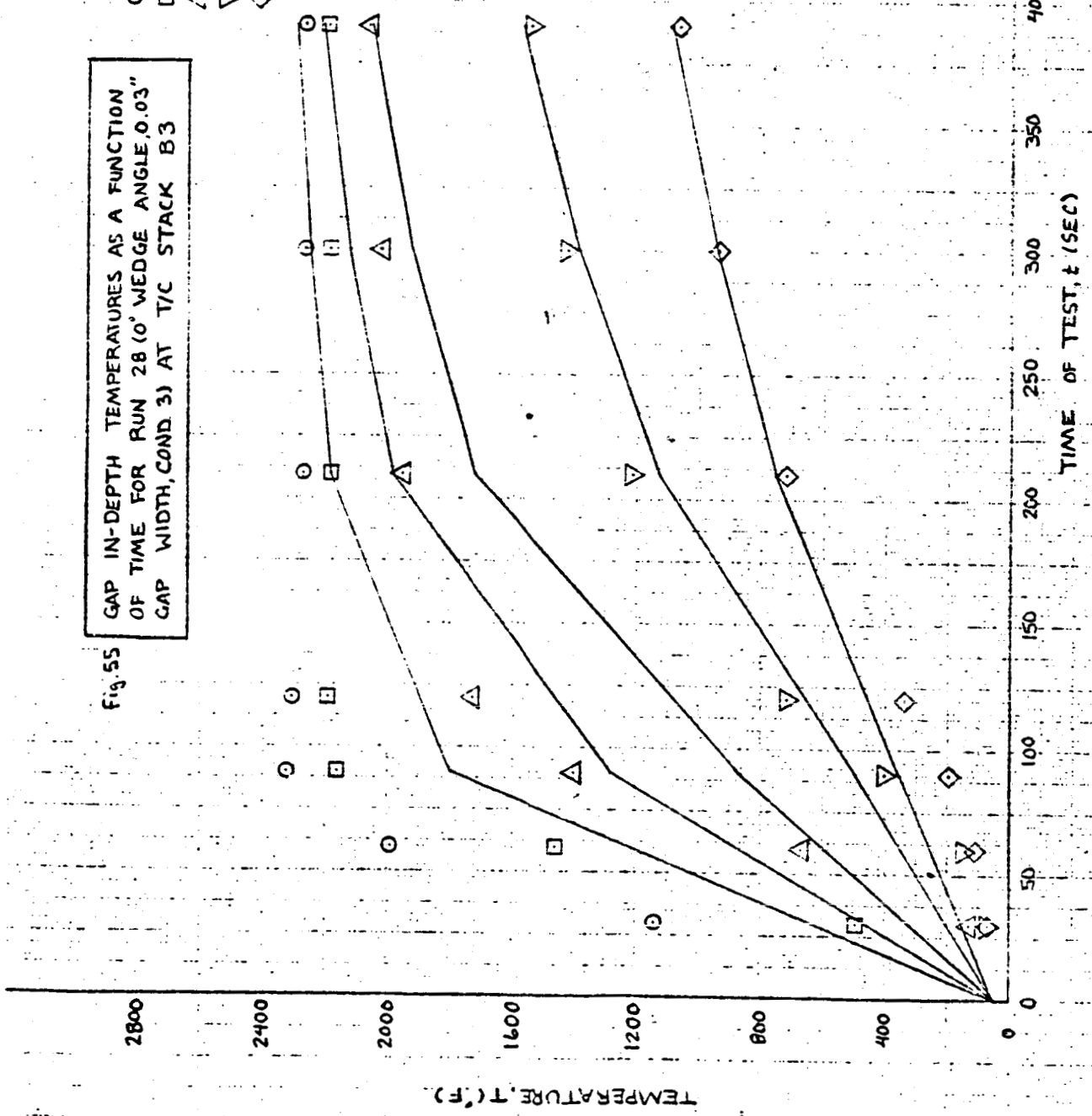


Fig. 56

BEST-FIT HEATING RATIOS FOR AMES
DOUBLE WEDGE TESTS FOR -6°
WEDGE ANGLE & 0.060" GAP WIDTH
FOR THERMOCOUPLE STACK B3

HEATING RATIO, $q(z)/q_{ref}$

• q_{ref} AT T/C STACK E2

RUN 18 (COND. 2)

RUN 20 (COND. 1-1/2)

RUN 17 (COND. 1)

GAP IN-DEPTH DISTANCE, z (IN.)

Fig. 57

BEST-FIT HEATING RATIOS FOR AMES
DOUBLE WEDGE TESTS FOR ZERO
WEDGE ANGLE & 0.060" GAP WIDTH
FOR THERMOCOUPLE STACK B3

HEATING RATIO, $q(z)/q_{ref}$

• q_{ref} AT T/C STACK E2

RUN 24 (COND. 2)

RUN 23 (COND. 1-1/2)

RUN 22 (COND. 1)

GAP IN-DEPTH DISTANCE, z (IN.)

HEATING RATIO, $q(z)/q_{ref}$

Fig. 58

BEST-FIT HEATING RATIOS FOR
AMES DOUBLE WEDGE TESTS
FOR 0° WEDGE ANGLE AND
0.060" GAP WIDTH FOR RUN 24

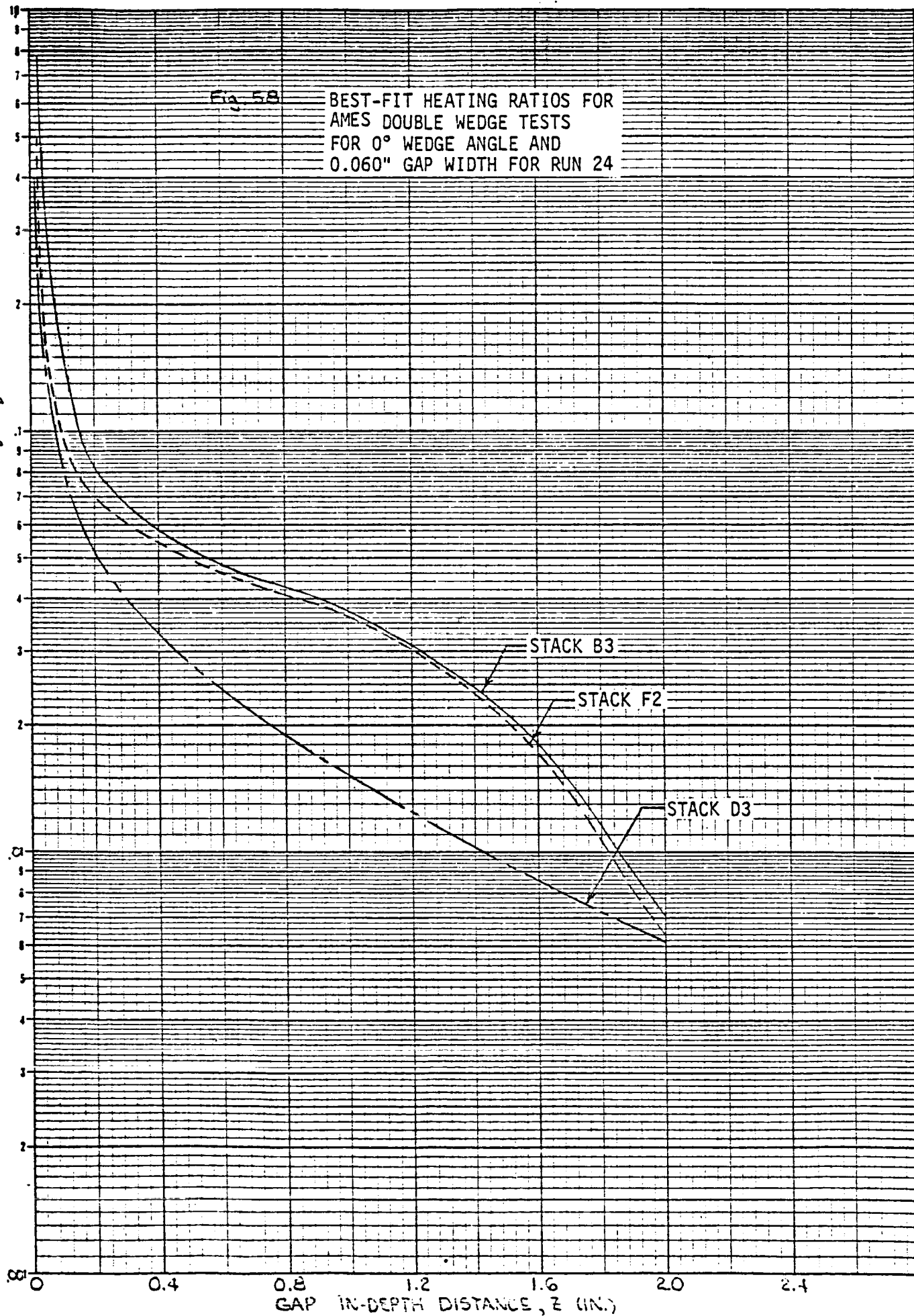


Fig. 59 BEST-FIT HEATING RATIOS FOR AMES
DOUBLE WEDGE TESTS FOR ZERO
WEDGE ANGLE & 0.030" GAP WIDTH
FOR THERMOCOUPLE STACK B3

HEATING RATIO, q_{ref}/q_{ref}

• q_{ref} AT T/C STACK E2

RUN 28 (COND. 3)

RUN 27 (COND. 2)

RUN 26 (COND. 1-1/2)

RUN 25 (COND. 1)

GAP IN-DEPTH DISTANCE, z (IN.)

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Fig. 60 BEST-FIT HEATING RATIOS FOR
AMES DOUBLE WEDGE TESTS
FOR 0° WEDGE ANGLE AND
0.030" GAP WIDTH FOR RUN 27

HEATING RATIO, $q(z)/q_{ref}$

STACK B3

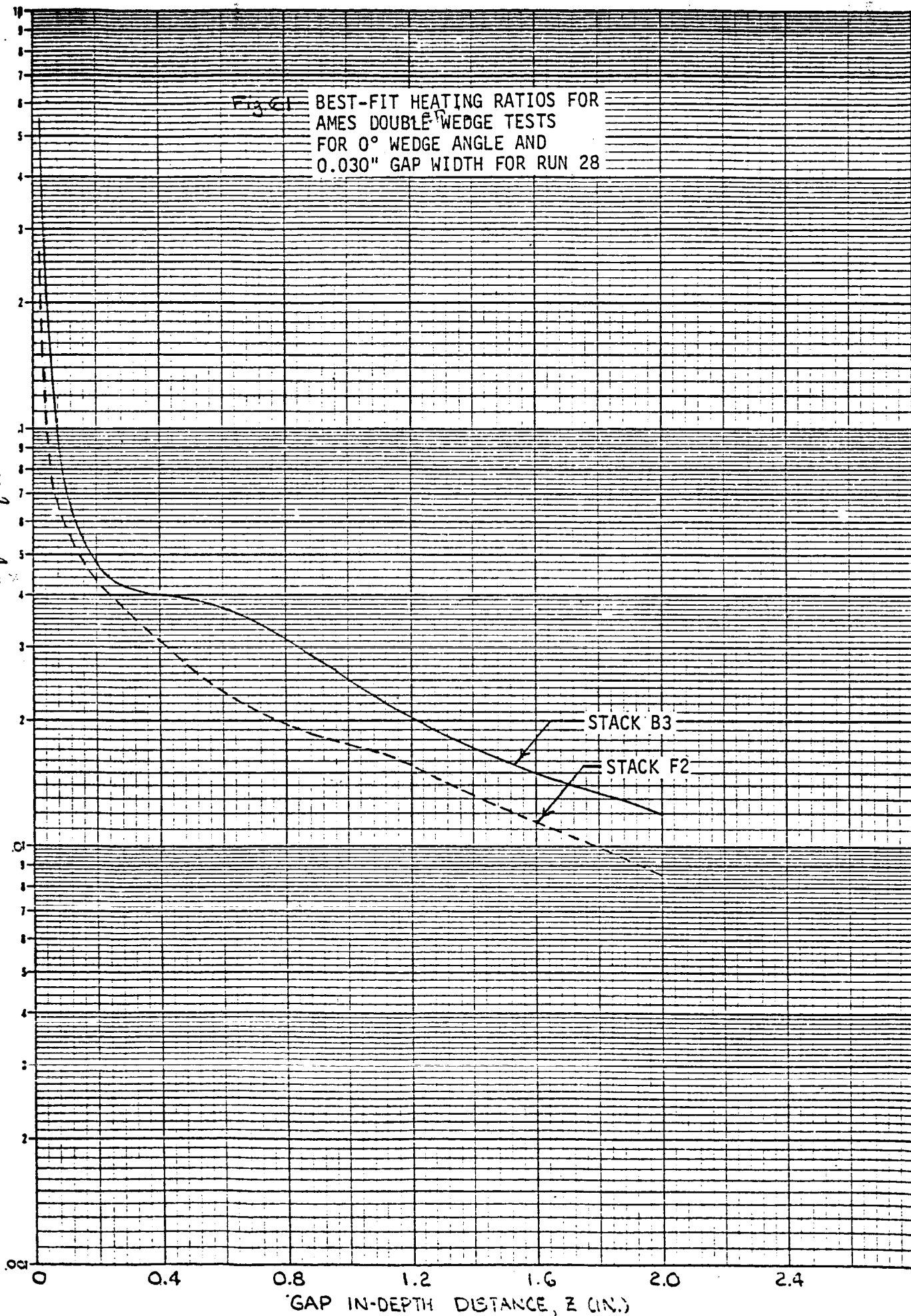
STACK F2

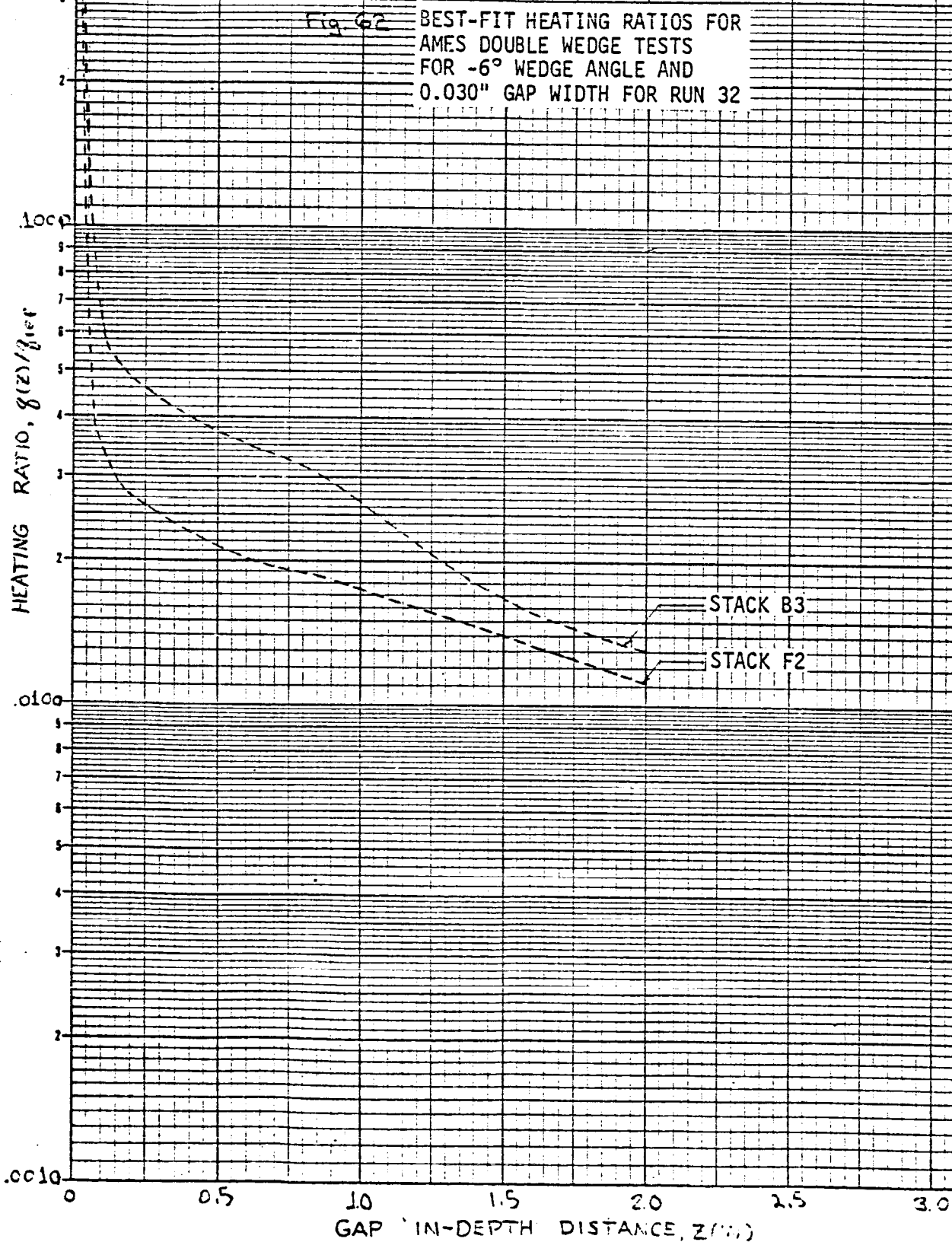
GAP IN-DEPTH DISTANCE, z (IN.)

OF POOR QUALITY

Fig. 61 BEST-FIT HEATING RATIOS FOR
AMES DOUBLE WEDGE TESTS
FOR 0° WEDGE ANGLE AND
0.030" GAP WIDTH FOR RUN 28

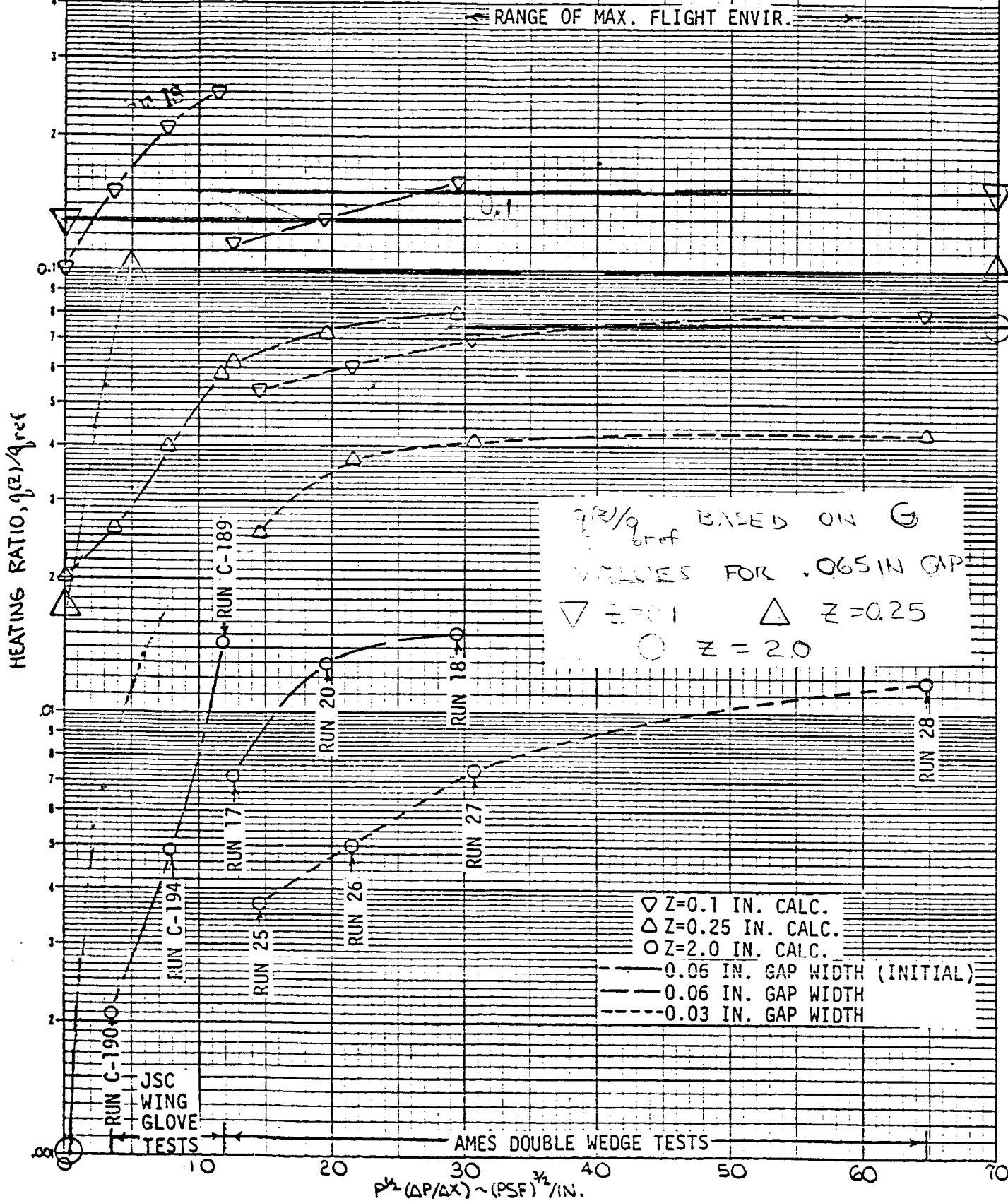
HEATING RATIO, $q(z)/q_{ref}$





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FIG. 63. COMPARISON OF HEATING RATIO FOR JSC
WING GLOVE AND AMES DOUBLE WEDGE TESTS

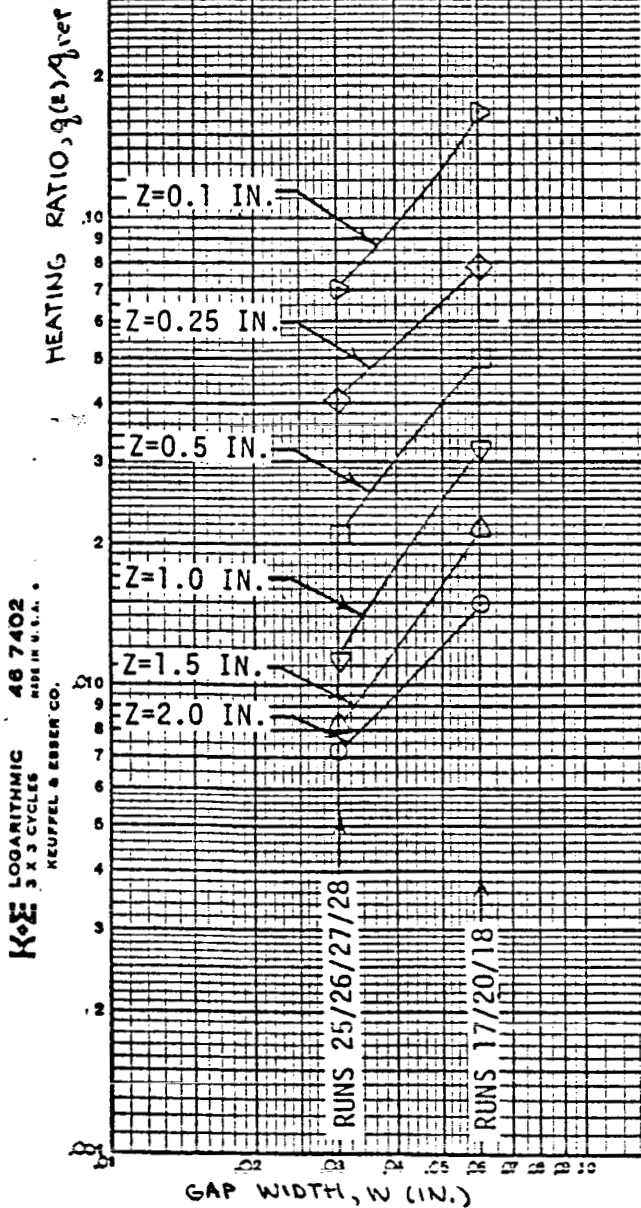


3 CYCLES X 70 DIVISIONS AD 0037-61

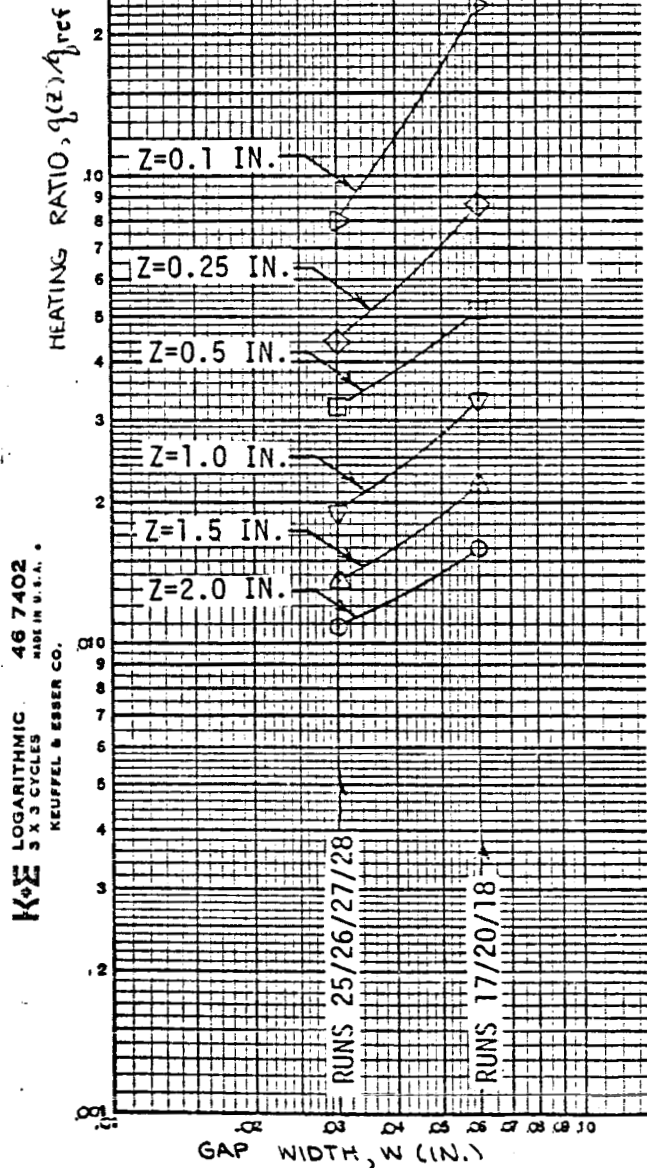
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 10-10-61

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FIG. 64. HEATING RATIO FOR AMES TESTS AS A
FUNCTION OF GAP WIDTH



A. $p^{1/2}(\Delta P/\Delta X) = 30 \text{ PSF}^{3/2}/\text{IN.}$



B. $p^{1/2}(\Delta P/\Delta X) = 50 \text{ PSF}^{3/2}/\text{IN.}$